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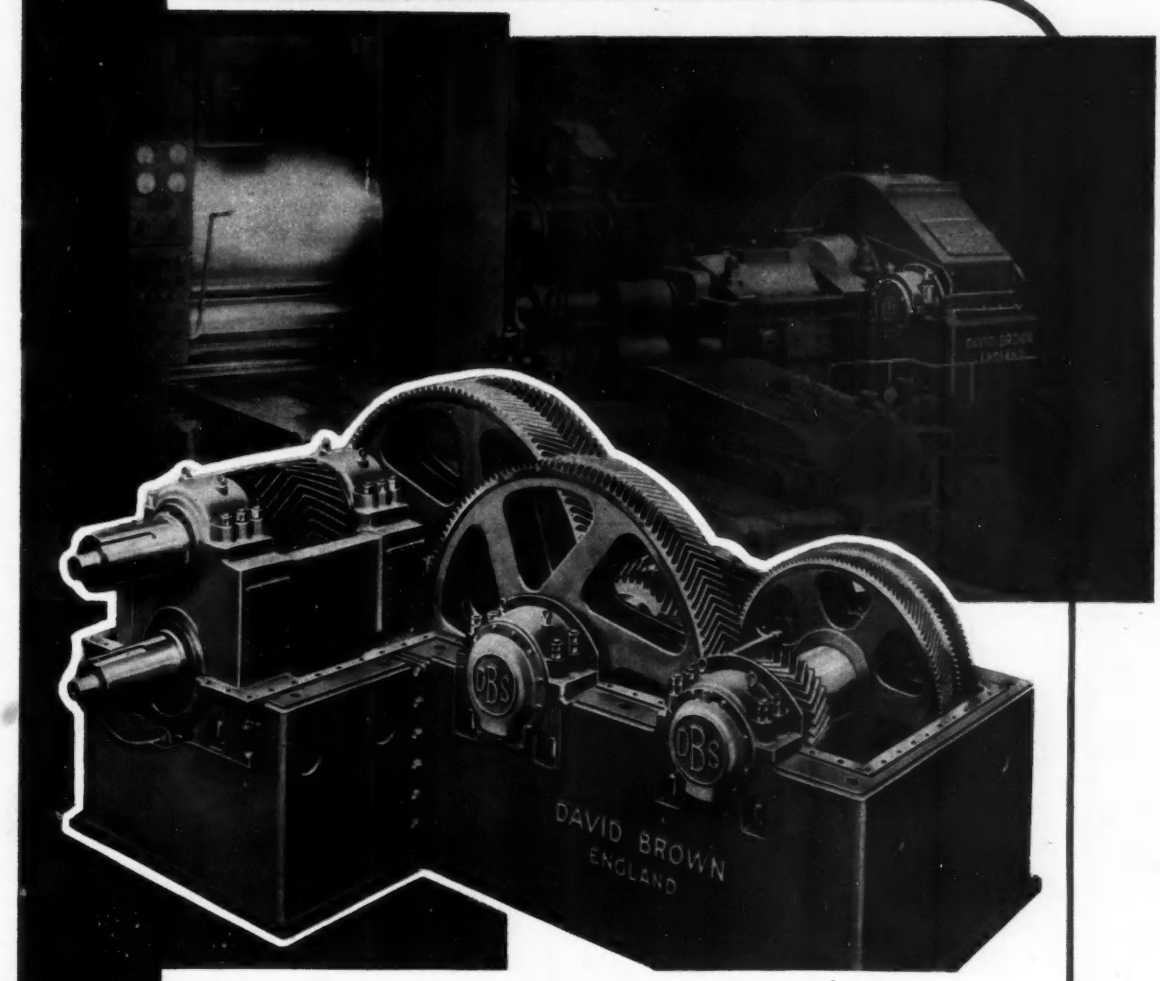

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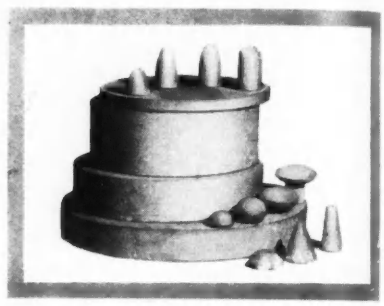

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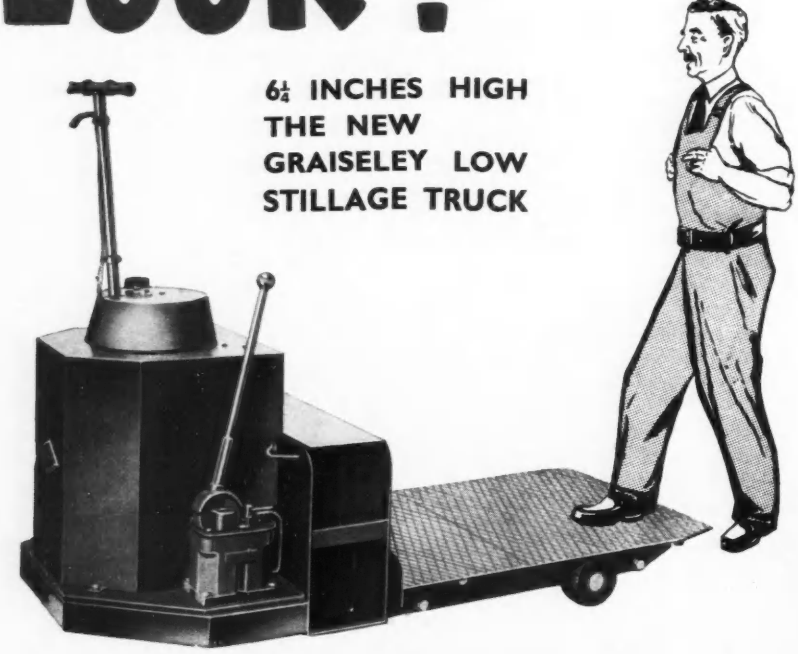

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THE ENGINEER

JUNE 10, 1955

Formation of British Nuclear Energy Conference

IN the light of recent rapid developments in the technology of nuclear energy, there has arisen an increasing need for a common ground between scientists and engineers where these developments can be discussed. An organisation has consequently been formed by the Institutions of Civil, Mechanical, Electrical and Chemical Engineers, and the Institute of Physics, which will be known as the British Nuclear Energy Conference. Its affairs will be managed by a board consisting of three representatives from each of those Societies. The chairman is Sir Christopher Hinton, and Sir John Cockcroft is one of its distinguished members. The secretary is Mr. Alexander McDonald (secretary of the Institution of Civil Engineers, Great George Street, London, S.W.1). The five societies will arrange for the presentation of papers dealing with nuclear energy subjects, and all members of the societies will be able to attend and take part in the discussions. The Conference will publish a Journal which will be offered for sale about four times a year, containing records of the papers, discussions, symposia and conferences conducted by the board. The board proposes to hold its inaugural meeting in the autumn at which a symposium of lectures will be delivered on the technology of nuclear energy and its applications. It proposes also to promote national and international conferences from time to time, and to arrange for British participation in international meetings. The expenses of the Conference will be met by the societies, although it should be self-supporting once it is fully established.

Plastics Exhibition

THE third British Plastics Exhibition and Convention was opened on Wednesday of last week at Olympia, London, and will close to-morrow. It is thought to be the most comprehensive plastics exhibition ever held and it makes particularly evident the very rapid expansion which continues in this industry. The present output of the plastics industry, including the whole range of industrial and domestic articles and fabrics, is now about 250,000 tons, which compares with the figure of 100,000 tons reached in 1949. Last year exported products alone realised £20,000,000. The industry employs approximately 75,000 and it spends several million pounds annually on research. One of the most significant aspects of the exhibition centres round the engineering section. Larger and faster cycling machines capable of producing mouldings of up to 120 oz and the development of machines for the vacuum forming of sheet plastics are outstanding exhibits in this section. New applications of plastics are particularly evident. Compression springs made of resin glass laminate are shown by a manufacturer, who also shows a bicycle with the handle bars and forks made of resin glass laminated tubing. The object of this exhibit is to demonstrate the ability to bond this tubing to metal and to point out the natural finish and non-corrosive properties of the tubing. Amongst many other applications of interest are those in the domestic field. They include the use of p.v.c. sheeting for garden furniture upholstery, which is unaffected by water, and is claimed to be cheaper than existing fabrics. Thermos flasks made entirely of plastics and the use of ventilated p.v.c. film for raincoats having sixty-four perforations per inch, which provide ventilation without any intake of moisture, are amongst other exhibits. Examples of oil resistant and butyl rubbers used for flame-resistant conveyor belts, hospital sheeting, inner tubes and for ozone-resistant wire insulation in electrical apparatus are shown. Another exhibitor shows plastic bones, which can replace infected human bone, splints and cuirass respirators designed to take over from the "iron lung" after the first few weeks of poliomyelitis. Plastics instrument sterilisers, hypodermic syringes and kidney bowls eliminating corrosion, breakage and chipping problems, are other applications in the surgical field. The changed and improved properties of plastics subjected to radioactive radiation are noted on another stand, their higher softening-points, for example, making them suitable for use in boiling water.

Airways Terminal in Kensington

IN a recent Parliamentary reply the Minister of Transport and Civil Aviation referred to the proposal for an airways terminal to be constructed over the so-called Cromwell Curve in Kensington. The site is in the triangle formed by the convergence of the District and Circle Lines between Gloucester Road, Earls Court and High Street, Kensington, stations. London Transport is acting as agent for British European Airways in this project, we are informed; its part is limited to the design and installation of decking over the site at street level to carry the terminal and ancillary buildings. The deck will be of reinforced concrete construction, carried on steel framing and columns, covering a little more than half the area of the triangle; it will, in fact, have an area of 140,000 square feet. The deck will be at a height of approximately 21ft above rail level and will have a roadway connection, at the south-west corner, to Cromwell Road and footway connections at roughly the south-east and north-east corners. The work of constructing the deck, which will be carried out without interference to normal railway traffic, is scheduled to start at the beginning of next year and will be in two stages. The first stage, which will cover the western half of the site, should be ready by the spring of 1957 and will permit erection of temporary buildings of a light nature so that this part of the site can be used by the airways authorities pending completion of the remainder of the decking. It is expected that the final stage will be completed and handed over to the airways authorities by the middle of 1958 for the erection of their permanent buildings.

"Atoms for Peace" Exhibition

THE mobile "Atoms for Peace" Exhibition, sponsored by the United States Information Service in co-operation with the United Kingdom Atomic Energy Authority, was opened last week on the South Bank in London and closes to-morrow, June 11th. This exhibition will, over the next five months, tour the country, visiting Belfast, Glasgow, Newcastle, Edinburgh, Leeds, Liverpool, Manchester, Sheffield, Nottingham, Birmingham, Cardiff, Bristol, and Southampton. It is housed in five large mobile trailers, each of which can be opened up on site to show a particular aspect of the use of atomic energy in the service of mankind by means of charts, diagrams, models, photographs, instruments and appliances, The first trailer by means of charts and diagrams deals with the potentialities of atomic energy and shows how it can replace the rapidly diminishing natural energy resources of the world. A second trailer using photographs and motion pictures gives some indication of what has already been achieved and work now in progress. The means of application and the widening uses of radio isotopes in agriculture are dealt with in the third trailer. Here illuminated screens are used with a commentary to show how radio-isotopes facilitate the study of plant life and trace diseases and their causes and effects. Many of the industrial uses to which radio-isotopes have been put in industry are shown in the fourth trailer, and a selection of actual examples and apparatus is included. Finally the uses of radio-isotopes in medicine, which are shown in the last trailer, give some idea of the vast new field which has opened in fighting and treating disease. In the centre of the exhibition a series of panels illustrates the work done in the United Kingdom in the field of nuclear energy.

Crompton-Lanchester Award

THE automobile division of the Institution of Mechanical Engineers has announced that the Crompton-Lanchester Medal for the session 1953–54 will be awarded to Professor J. J. Broeze for his paper entitled "Automobiles and Petroleum: Past, Present and Future." This paper was presented by the author last year at the Delft summer meeting. The award is made in recognition of any outstanding service which may be considered to have a special influence on the advancement of automobile engineering. The medal is struck in bronze and was derived by the combination of two awards granted by the Council of the late Institution of Automobile Engineers. It bears the representation of the heads of the distinguished engineers, Colonel R. E. B. Crompton, C.B., F.R.S., and Dr. F. W. Lanchester, F.R.S., who were both pioneers in this field. The medal will be presented if possible, to Professor Broeze at the annual general meeting of the Automobile Division on October 4th this year.

Timber Development Association

THE Timber Development Association has published its twenty-first annual report for the year 1954. It contains a review of the activities of the association, which include advisory services, publicity, design, research and education concerned with all the uses to which timber may be put. At the association's annual general meeting, the president, the Earl of Feversham, spoke of the present-day uses of timber, and stressed its importance as a renewable crop. Our timber in the main came from the under-developed parts of the world, he said, which provided an industrial country such as ours with its most promising export markets. In quantity, practically all the minerals and fuels used since the dawn of civilisation had, in fact, been used in the last 150 years, Lord Feversham continued, and the world was facing a serious depletion of its mineral resources; timber was the only bulk supply of raw materials which, with proper husbandry, was virtually inexhaustible. Solar energy, he contended, was the source of all energy and the simplest and most direct way of utilising it was by growing trees.

Association of Consulting Engineers

THE annual report of the Association of Consulting Engineers for the year ended April 30, 1955, records that thirty-seven new members joined the Association during the year, and the total membership is now 403. The report includes notes on the work of the Association's various committees—on general conditions of contract and on model forms of agreement for instance—and on the agreement with the Export Group for the Constructional Industries for submitting comprehensive offers for the design and construction of civil engineering works overseas. So far sufficient time has not elapsed for it to become known how the agreement is working, it is stated. Other developments noted in the report include the prospect of more work at home, and the success of the Association's exhibit at the British Trade Fair in Baghdad.

Vertical Boiler Locomotives

By R. A. S. ABBOTT*

No. III—(*Continued from page 765, June 3rd*)

The study of the history of the industrial locomotive is a fascinating subject, quite outside the scope of ordinary railway and locomotive literature, and one which offers a wide field for research. For many years the writer has made the industrial and light locomotives with vertical boilers his special interest, and as no previous history of this type of locomotive has ever been published it is hoped that this excursion into a little explored by-way of locomotive engineering will prove welcome to both the engineer and historian.

Merryweather Tramcar Engine

THE early experimenters with steam tramcars evidently soon came to the conclusion that an independent locomotive would be much more satisfactory in many ways to an engine combined with the tramcar, and so in 1875 we find that Messrs. Merryweather and Sons, of Greenwich, constructed a small experimental locomotive. The vertical boiler was fitted with "Field" tubes and was similar in construction to those fitted to the firm's fire-engines since 1861. Two cylinders, 6in diameter by 9in stroke, were placed horizontally on the centre lines of the axles so that the vertical motion of the bearing springs, of the coil type, should not affect the action of the valve gear. A sheet iron box protected the motion from the dust.

A water tank was fitted at one end and a coke bunker at the other, leaving a clear gangway on each side of the locomotive. The exhaust steam was superheated in a box arranged at the bottom of the chimney uptake, being conducted thence by pipes, passing through the ashpan and inside the firebox. This arrangement was found to heat the steam sufficiently to render it invisible. The iron dish surrounding the uptake was placed there to catch the dislodged scale and prevent it falling into the "Field" tubes. The length of the cab was only 6ft 6in, and the total weight of the locomotive with fuel and water was under 4 tons.

A second locomotive appeared in 1876, and this also had a Merryweather and Field boiler, with superheating apparatus and scale catcher as in the earlier one. A vertical steam cylinder was placed on either side of the vertical boiler, driving through suitable gearing to one axle, the wheels being coupled by rods. The total weight was only 5 tons, and it is understood that in order to obtain proper adhesion when ascending steep inclines, part of the tramcar weight could be thrown on to the locomotive frame.

The locomotive had the appearance of being merely the power bogie of a combined car, but as the weight was only taken on hills it was presumably a separate machine. These two locomotives were both sent to Paris. The issue of *Engineering* for March 9, 1883, illustrated and described these two locomotives.

Many years later, about 1907, a vertical boiler inspection locomotive was built by Merryweathers for the Buenos Ayres and Pacific Railway, and this machine was fully described and illustrated in *The Locomotive* for 1907, page 133.

Locomotives from Caernarvon

Although primarily intended for the narrow gauge lines in the local slate and granite quarries of Caernarvonshire and Merioneth, the small vertical boiler locomotives constructed by Messrs. de Winton and Co., Union Works, Caernarvon, were afterwards supplied for use further afield and for gauges up to 4ft 8½in. Exactly how many were built is not known, probably about fifty, but thirty-seven two-cylinder and two single-cylinder examples have been traced, all built between 1875 and 1897. Of the single-cylinder design little is known beyond the fact that they had direct drive and double-flanged wheels, and being very small could be used closed up to the working face in quarries for supplying steam to rock drills. Two were owned by the Glyn-Rhonwy Slate Quarries at Llanberis.

The 1ft 11½in gauge locomotives (Fig. 15) of the two-cylinder type, had a solid plate frame outside the disc wheels, and being without springs the bearings were fixed directly in these frames. At the front end was the small water tank, at the other end the coal bunker, with the boiler mounted very low in the centre between the axles. The fire was fed through a trapdoor in the footplate and the coal slid down a chute on to the grate. These boilers were 2ft 7½in diameter and 4ft 10½in high, made of Low Moor iron and fitted with seventy-six tubes of 1½in diameter; grate area, 3·4 square feet. The Ramsbottom safety valve, fitted on a bracket on the left-hand side, blew off at 120 lb per square inch.

On most locomotives the chimney was in the top centre of the boiler above the smokebox, but as condensed steam and rainwater was found to run down the short chimney and cause the top tube plate to corrode, the design was altered in the later examples to provide for a smokebox placed staggered fashion in advance of the boiler top. The two vertical cylinders were fixed to the boiler front by two steel plates, one on either side of, and partially embracing, the boiler. The drive was direct on to the front axle without gearing, the connecting-rod big-ends being of the marine type.

The "Victoria," built in 1897, differed in being fitted with a free-standing launch type engine and driving the axle through an intermediate shaft. This can be seen in Fig. 16, which also shows the offset type of smokebox. It is thought that this was the last de Winton locomotive built. The valve gear was originally Joy's, but later Stephenson's gear was adopted in conjunction with a special form of slide valve designed by Charles Cousins, chief draughtsman during the 1880s; the reversing quadrant was on the right-hand side of the footplate. Other dimensions were: wheels 1ft 8in diameter; wheel base—this varied from 4ft to 4ft 4in length over frames 8ft 6in; overall width, 3ft 6in; height to top of chimney, 6ft 9in. This class was used at the Penrhyn Quarries, Bethesda; Pen-yr-Orsedd Quarry, Nantlle; Cilgwyn Quarry, Carmel; Alexandra Quarry, Rhosgatfan; Oakley Quarries, Blaenau Festiniog; Dorothea Quarry, Tabysarn; and Greave's Llechwedd Quarry, Blaenau Festiniog.

A drastic variation from the standard design was made in the case of the "Arthur," built for the Pen-yr-Orsedd Quarry in 1890 and illustrated here in Fig. 17. In this design the water tank was placed close to the boiler and the engine at the front end of the frame with the drive from the crankshaft to the front axle by outside cranks and coupling rods. Whether this particular locomotive was the only one produced to this pattern is not known.

The 3ft gauge series, Fig. 18, were slightly larger and had inside frames. The dimensions were: boiler, 2ft 10in diameter and 5ft 3½in high; grate, 2ft 1½in diameter;

* Member, Newcomen Society; Member, Industrial Locomotive Society.

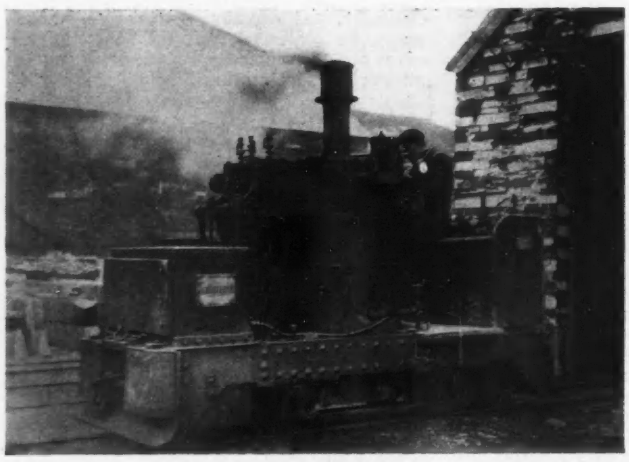


Fig. 15—de Winton locomotive "Pendyffryn" for 1ft 11½in gauge, Pen-yr-Orsedd quarry, Nantlle

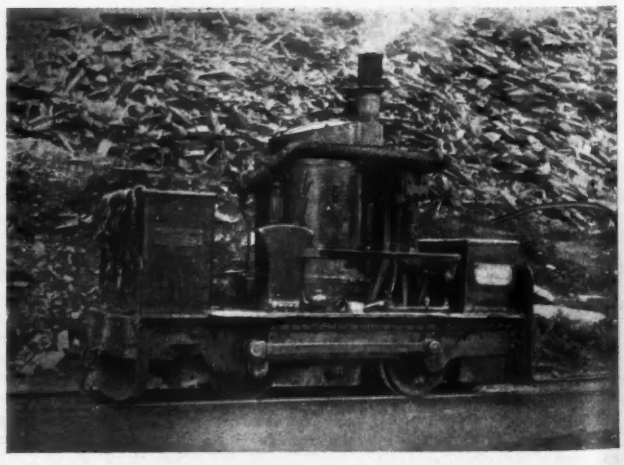


Fig. 16—de Winton locomotive "Victoria," built in 1897, with geared drive, Pen-yr-Orsedd quarry, Nantlle

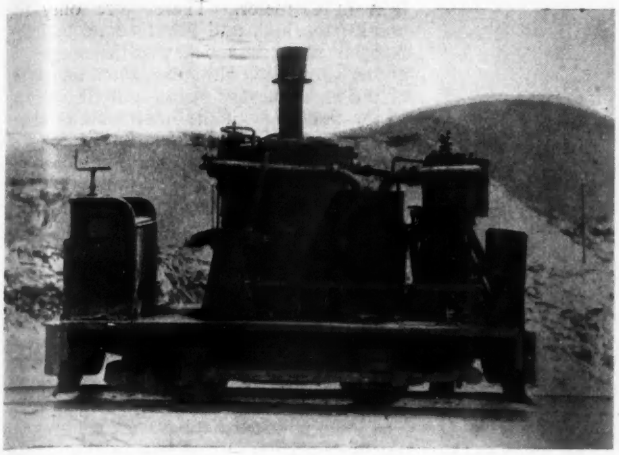


Fig. 17—de Winton locomotive "Arthur," built in 1890, with rod drive, Pen-yr-Orsedd quarry, Nantlle

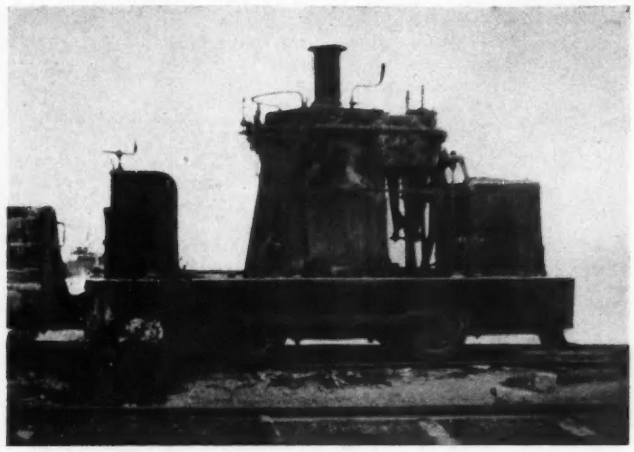


Fig. 18—de Winton locomotive "Watkin" for 3ft gauge, built in 1893 for Darbishires, Ltd., Graiglwyd quarry, Penmaenmawr

pressure, 120 lb per square inch; wheels, 1ft 8in diameter; wheel base, 4ft 5in; length over frames, 11ft 7in; overall width, 4ft 3in; the price of one of these locomotives in 1894 was £430. The illustration, Fig. 19, is an underside view of one of the 3ft gauge locomotives, and is interesting in that it shows how the frames were formed with an outward bulge to accommodate the firebox; this form of construction was also used on locomotives built for the narrower 1ft 11½in gauge, but was not universally employed. The view also shows the coal chute from the footplate down to the firegrate, and it will be seen that the axle bearings were simple plummer blocks attached direct to the frames.

Locomotives of this gauge went to Messrs. Darbishire's Graiglwyd Quarries, Penmaenmawr, and to Brundrit and Co., Penmaenmawr. The original cylinder dimensions of all these locomotives are doubtful, as most of the survivors have been rebored at least once, but recent measurements show that cylinders of 6½in diameter by 10in stroke and 6¼in diameter by 12in stroke are to be found on the 1ft 11½in gauge, and 5¾in diameter by 10in stroke and 6¾in diameter by 12in stroke on the 3ft gauge. The weights are likewise uncertain, as some locomotives have had thick slabs of steel plate laid flat on the top of the frames on either side of the boiler to increase the adhesion. Two of the Penmaenmawr locomotives that have been so treated weigh 5 tons 15 cwt, but otherwise the average weight on both the narrow gauge engines appears to have been 4½ tons empty and 5 tons when in working order.

The only example of a standard gauge de Winton locomotive known to the writer is illustrated in *The Locomotive* for 1905, page 138. It is of interest to record that although the last de Winton locomotive was built in 1897, the firm quoted for the supply and delivery of one to the phosphate company operating on Christmas Island about 1900.

Balmforth Design

Messrs. Balmforth Bros., Peelings Foundry, Rodley, near Leeds, were manufacturers of locomotive steam cranes, contractors' locomotives, hoists, and all kinds of lifting machinery. Their contractors' locomotives were of a very unusual design, combining vertical boiler, outside sloping cylinders and outside frames, the whole being carried on four half-elliptic springs mounted above the frames, Fig 21. Just how many were built cannot now be ascertained, but fortunately two such locomotives are still owned by Mr. W. Hunter, proprietor of the extensive gravel pits at the south end of Walney Island, and through the kindness of Mr. M. Carter, of Barrow, it has been possible to record a few dimensions. The wheels are 1ft 10in diameter; cylinders, 8in diameter by 14in stroke; and the gauge is 3ft.

The curious valve gear should be noted; the Stephenson link motion actuates, through a rocking shaft, the long rod seen on the outside of the frames extending from the front of the locomotive right to the valve chest. The connecting-rods are of round section with marine type big ends, Fig. 20. When new, the boilers had cross tubes and worked at 60 lb per square inch. The present-day weight is 7 tons and the average load hauled with ease is 60 tons.

As to the period during which Messrs. Balmforth manufactured this class of locomotive, it is known that one of these Walney Island locomotives was purchased second-hand in 1896, and was said at that time to have been twenty years old, so the date of building would be *circa* 1876. Another locomotive of this make worked at Newby Brickworks, Annan, bearing the name "Ivanhoe." It started work prior to 1890 and was scrapped in 1910. A small engraving of a Balmforth locomotive will be found in the firm's advertisements which appeared in *Engineering* during the 1880s, where it is also stated that all boilers then being made were fitted with Fox patented corrugated steel fireboxes.

Kitson Engines

Three experimental locomotives with vertical boilers were built in 1878 at the famous Airedale Foundry of Kitson and Co. Ltd., Leeds, and although not supplied to any specific order, two of them eventually

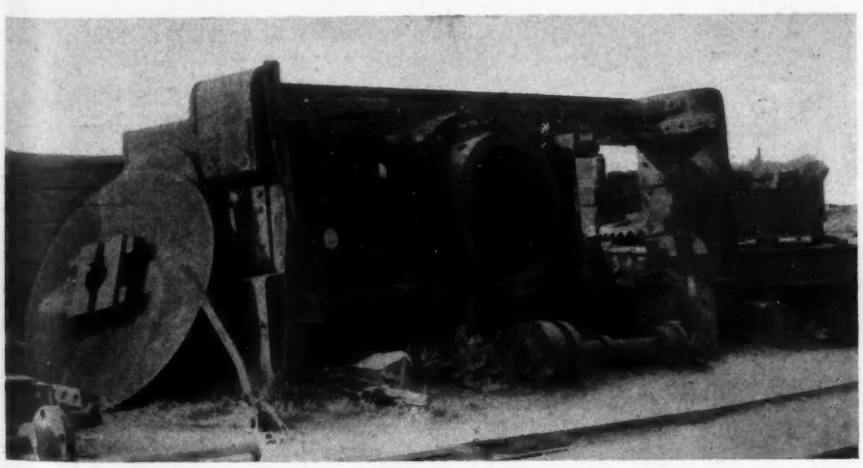


Fig. 19—de Winton locomotive frame showing outward bulge to accommodate the firebox

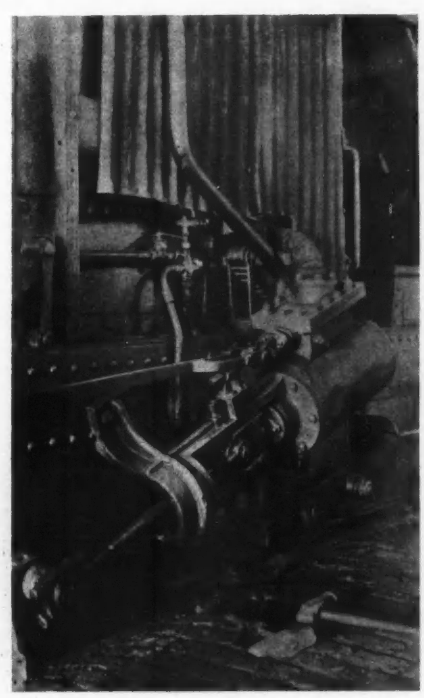


Fig. 20—Balmforth locomotive showing marine type big ends

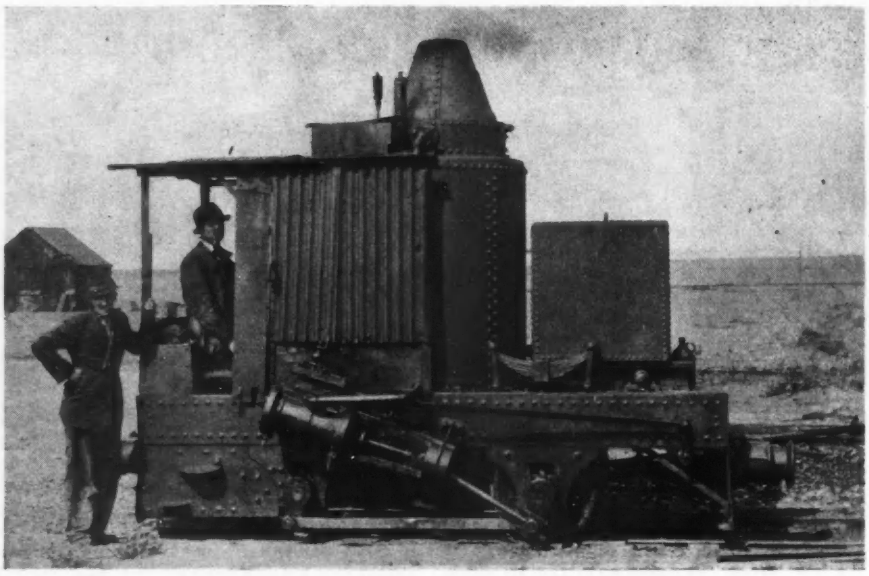


Fig. 21—Locomotive by Balmforth Bros., of Rodley, at the gravel pits on Walney Island

worked on the tramways at Hamburg and Rouen, while the third was purchased by the Great Eastern Railway Company for use on its Millwall Extension line. This latter locomotive was illustrated on page 262 of *The Locomotive* for 1910 and was there described as having two cylinders placed vertically and driving a shaft placed transversely between the two axles, from whence the drive was taken to the running wheels by coupling rods. These cylinders were on either side of the vertical boiler and were visible through the side windows. The four coupled wheels were 2ft diameter on a wheel base of 4ft 6in. The boiler, fitted with 130 cross water tubes, provided a heating surface of 80 square feet, while the grate area was 3·17 square feet. It was designed for a working pressure of 150 lb per square inch and had a diameter of 2ft 5in with an extreme height of 5ft 6in, while the outer shell was made in two parts, so that the top part could be lifted for inspection and repairs. The overall height to top of chimney was 12ft 8½in and the total length of the locomotive over body was 10ft 8in, with an extreme width of 7ft 1¼in. The multitubular air-cooled condenser in the roof gave a cooling surface of 452 square feet.

These three locomotives may not have been exactly alike in design, for the late Dr. Whitcomb in his *History of the Steam Tram* says that the cylinders were placed high up outside the frames and inclined slightly from the horizontal, and that Kitson valve gear was fitted. Due to the closing down of the Airedale Foundry as a locomotive works, and the destruction and loss of most of the records, there now seems little chance of this doubtful point being cleared up.

Greenwood and Batley

In 1878, Greenwood and Batley, Ltd., Albion Works, Leeds, constructed for Loftus Perkins a somewhat larger vertical boiler tramway locomotive, Fig. 22, of a similar design to that sent to Brussels by the Yorkshire Engine Company, in 1874. The engine, however, was arranged for triple expansion, the high-pressure cylinder having a diameter of 3¼in, the intermediate cylinder a diameter of 5½in, while the low-pressure cylinder was 7½in in diameter. There were only two cranks, the high and intermediate cylinders being arranged in tandem with the two pistons on the same rod. The steam acted on the top of the high-pressure piston and then passed to the underside of the intermediate piston, finally passing to the low-pressure cylinder, which was double-acting; the common stroke was 9in. The gear ratio between crankshaft and countershaft was 4 to 1, with the final drive by coupling rods to the 2ft diameter wheels set on a wheel base of 4ft 3in, the gauge being 4ft 8½in.

The Perkins boiler provided a heating surface of 90 square feet, with a grate area of 3 square feet, and carried a working pressure of 500 lb per square inch. The boiler feed water was supplied by one steam donkey pump and one mechanically driven pump. The brass condenser tubes were 6ft high and ½in diameter and together had a cooling surface of 1500 square feet.

This locomotive was 10ft long, 7ft wide and 9ft 8in high excluding chimney; it weighed in working order 6 tons. It was tried on the Leeds Tramways but does not seem to have done any useful work.

Ransomes and Rapier

Ransomes and Rapier, Ltd,, Waterside Works, Ipswich, was established in 1868 for the manufacture of general railway plant, such as chairs, rails and points, but a few years later the firm commenced building various kinds of narrow-gauge locomotives, among which was a series of vertical boiler inspection locomotives, the prototype of which had originally been designed and built for export to one of the Colonies. The illustration, Fig 23, is from Ransomes and Rapier's official photograph No. 90 and it is understood that a woodcut of this photograph appeared in a catalogue for the year 1880, which gives some indication of the date when these locomotives were being built. As very little appears to be known about these locomotives, and the writer has as yet found no other contemporary account, it will be convenient here to quote from the makers' catalogue: "Steam Carriage suitable for rails of 18–20 lbs. per yard. . . . This engine has since done exceedingly good service, both as an auxiliary on ordinary railways and as principal Engine

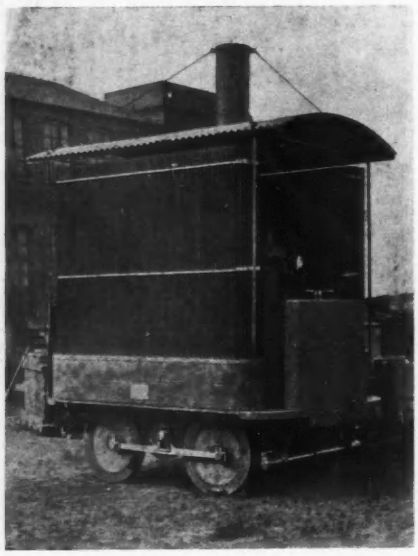


Fig. 22—Loftus Perkins high-pressure tram locomotive by Greenwood and Batley, Ltd., 1878

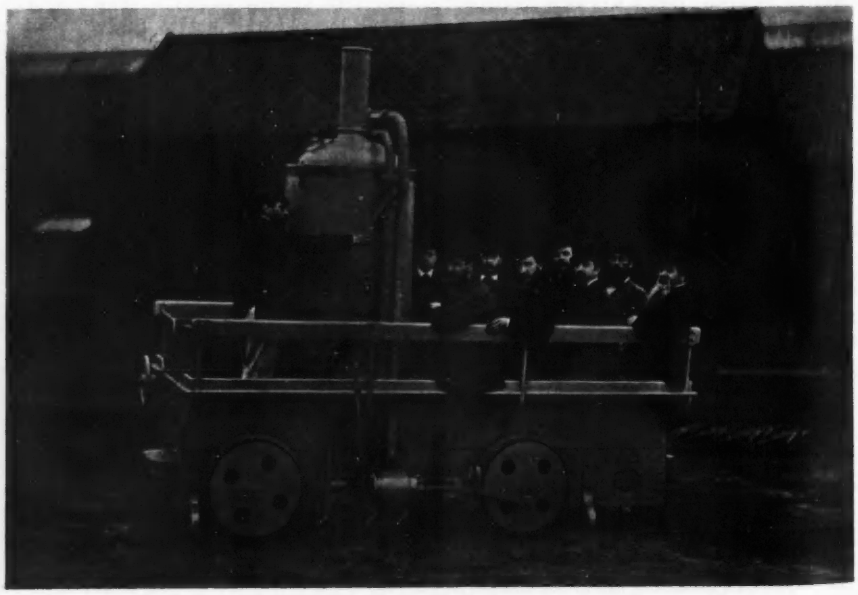


Fig. 23—Ransomes and Rapier's inspection locomotive, circa 1878

on light railways. It is practically a combination of Engine, Tender, Brake and Carriage, all in one; and it is the least expensive contrivance for travelling 20 miles an hour which has yet been produced. For economy of space, the boiler is made of the vertical type, with grate surface and heating surface so ample as to enable a good supply of steam to be easily maintained, even when burning wood or refuse fuel. The Engine has two cylinders, and is fitted with reversing gear, and all other fittings usual in the best locomotive work. It can be made of any gauge from 2 feet to 5 feet 6 inches, according to the gauge of the railways in the locality. If there are no railways, the best gauge will be 3 feet or 3 feet 6 inches. We build these Engines on stock, and can finish them at short notice to any of the following gauges, viz., 3 feet, metre, or 3 feet 6 inches. The example here given has the following leading features and dimensions :—

" Maintained speed 20 miles per hour, with light loads.

" Maximum train load at 8 MPH. on level, 80 tons.

" " " " 5 MPH. on 1 in 100, 40 tons.

" " " " 3 MPH. on 1 in 35, 20 tons.

" Supply of coal and water for 30 miles.

" Weight in working order 6 tons.

" Cylinders 7 inches diameter by 10 inches stroke, wheels 1 foot 8 inches diameter.

" Length overall 11 feet.

" Room for 6 or 8 passengers.

" Fitted with locker to contain mails and parcels.

" Price of the machine, if fitted with roof, £480, price for enclosing with glass windows £40."

These locomotives were spring mounted, and all appear to have had disc wheels, but not always of the same pattern, some being solid, while others had the circular holes as shown in the illustration.

(To be continued)

Silicon Alloy Junction Diodes for Power Supply Application

By J. SHIELDS, B.Sc.*

The development of convenient methods of growing large single crystals of germanium and silicon has led in recent years to the production of many low current semi-conducting devices and their application in circuit construction. At present germanium is being used to a greater extent than silicon, but the ability of silicon devices to operate satisfactorily at temperatures as high as 200 deg. Cent. suggests that, in future, silicon will replace germanium in many applications. Recently, widespread interest has been shown in the application of germanium to the field of power rectification : this article summarises work carried out in the B.T.H. research laboratory in making experimental silicon rectifiers and in examining their characteristics.

SILICON in its pure state is a poor conductor, but disturbances in the crystal lattice, caused, for example, by the presence of small amounts of impurities to the extent of less than 1 part in 10^6, can cause considerable changes in its conductivity. Two main classes of impurities are recognised, " donors " and " acceptors," the mechanism of conduction depending on which class of impurities is present in excess. " Donor " impurities result in a surplus of free electrons which conduct current by the passage of negative charges through the crystal, a crystal with excess electrons being called " *n*-type." Phosphorus, arsenic and antimony act as donor impurities in silicon. " Acceptor " impurities result in a deficiency of electrons creating " positive holes " which are mobile and can conduct current through the crystal.[1] A crystal with a deficit of electrons is called " *p*-type." Aluminium, boron, gallium and indium act as acceptor impurities in silicon.

A change from *p*-type to *n*-type material inside a crystal results in a junction which exhibits rectifying properties. This *p-n* junction has a low resistance to current flow from the *p* to *n* region, but a very high resistance to current flowing from the *n* to *p* region.

Two kinds of *p-n* junction have been produced :—

(*a*) Junctions prepared by careful control of conditions during the growth of the single crystal (commonly called " grown junctions ").

(*b*) Junctions prepared by the diffusion or alloying of impurities into the crystal after growth (commonly called " diffusion junctions " or "alloy junctions ").

In the present investigations the junctions considered are of the " alloy " type.

Materials and Diode Construction

Junction devices are prepared from wafers from single crystal silicon cut perpendicular to the direction of growth. These single crystals have been grown in the laboratory by the Czochralski technique—a single crystal is shown in Fig. 2. For the purpose of the present investigation wafers have been taken from a selection of *n*-type single crystals of electrical resistivities from 0·7 to 10 ohm-centimetre.

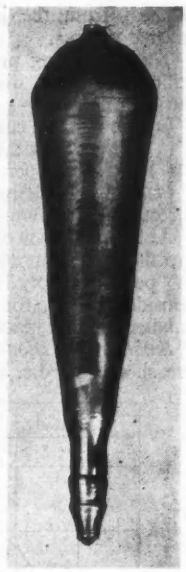


Fig. 2—A single crystal of silicon grown by the Czochralski method

The *p-n* junction diodes are prepared by alloying, at high temperatures, donor and acceptor impurities to opposite faces of a silicon wafer. In this instance aluminium is used as the acceptor impurity and antimony as the donor. It has been suggested by Herold[2] that the junctions should be grown by deposition from the solid solution of silicon and the impurity during the cooling cycle, the junctions being situated between the unmelted silicon and the deposited solid solution. A schematic representation of an alloy diode is shown in Fig. 3. After assembly the diode is carefully cleaned and then insulated from atmospheric contamination.

Electrical Properties of Junction Diodes

Fig. 1 gives the d.c. characteristics of several kinds of silicon alloy junction diodes constructed in the B.T.H. research laboratory. The diodes have ranges of forward currents from milliamperes to tens of amperes.

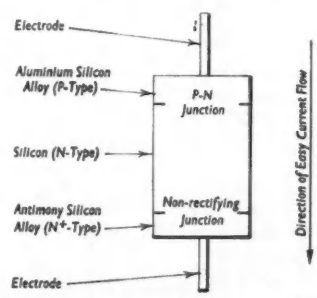


Fig. 3—Schematic representation of an alloy diode

Most rectifying diodes have a particular field of application governed mainly by their power handling capacity in the forward direction of current flow, although diodes of type *B*, Fig. 1, are of interest because of their unusual reverse characteristics. This power handling capacity is dependent mainly on the area of the rectifying junction, the ambient temperature, the efficiency of removal

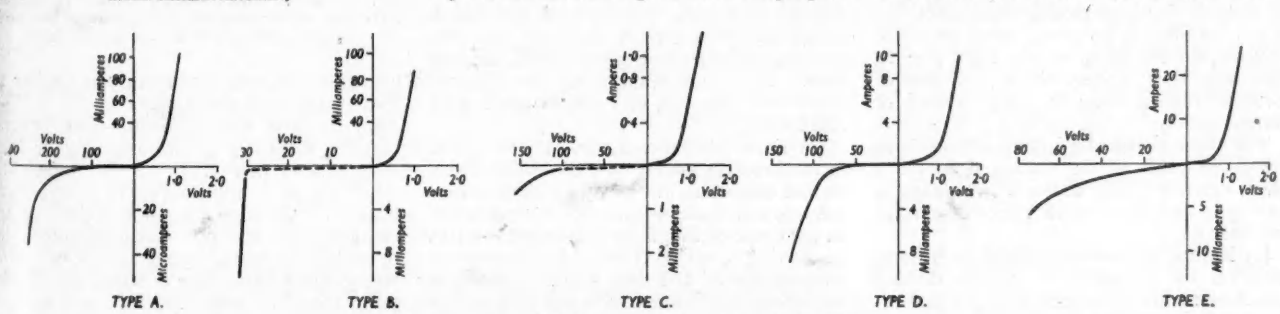


Fig. 1—Characteristics of various silicon alloy junction diodes

* B.T.H. Research Laboratory

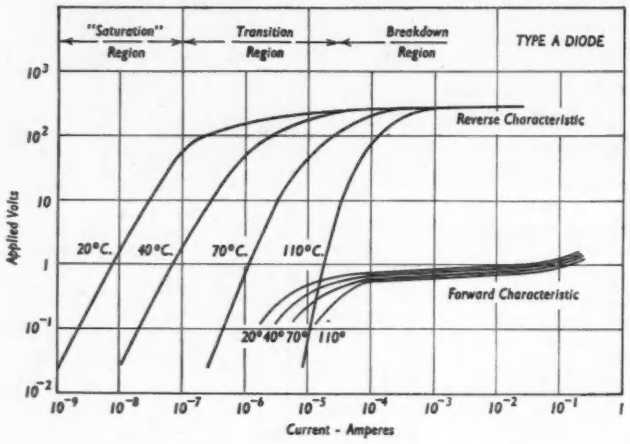
of heat from the junction, and the peak inverse voltage.

The interesting properties of these units, which we shall discuss in the following paragraphs, are :—

(*a*) Low reverse currents as small as 10^{-9}A.
(*b*) Large rectification ratio at 1V, $\sim 10^6$.
(*c*) Ability to operate at high temperatures.
(*d*) Power dissipation in the forward direction of current flow.

Although diodes of type *D* and *E* in Fig. 1 are the more important from considerations of power supply applications, we shall consider briefly, for comparison, diodes of smaller power capacity, of type *A*.

Small Area Diodes, Type A.—In Fig. 4 are shown the d.c. characteristics on a log-log plot (to clarify their variation with temperature) of a typical small area silicon diode of junction area 0·001 square centimetre.



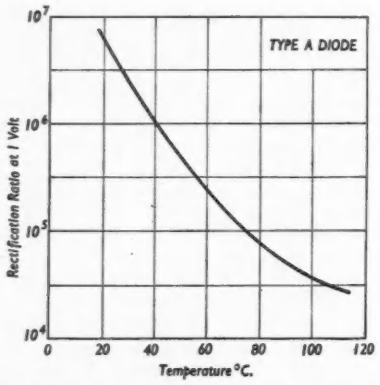


Fig. 4—D.C. characteristics of a type A small-area silicon diode of junction area 0·001 square centimetre. To clarify variation with temperature these characteristics are shown on a log-log plot

(*a*) Forward characteristic.—At 1V this diode gives ~100mA of current corresponding to a current density of 100A per square centimetre. The power loss in the junction is 100mW, which can easily be dissipated without causing any appreciable temperature rise. At current densities greater than 200A per square centimetre, however, the slope of the forward current plot, $d(\log V)/d(\log I)$, decreases, thus leading to high values of forward voltage drop for large values of current density.

The effect of increase in temperature is to lower the value of the voltage drop for a given current. This decrease in voltage is most pronounced at small values of current and voltage.

(*b*) Reverse characteristic.—In the reverse direction the characteristic can be divided into three main regions, indicated in Fig. 4 :—

(1) " Saturation " current region.

(2) Transition or intermediate current region.

(3) Breakdown or high current region.

(1) " Saturation " current region.—This part of the reverse characteristic is noted for its high resistance which decreases exponentially with temperature. At temperatures from 20 deg. to 110 deg. Cent., the resistance at −100V is seen to vary from 1000 megohms to 1 megohm.

Although this factor clearly varies rapidly with temperature its very high initial value is such that even at temperatures as high as 200 deg. Cent. the reverse resistance is still high. For a germanium diode of similar power ratings the reverse resistance is smaller by a factor of the order of 10^3 and a similar rapid variation of resistance with temperature is such that, at 75 deg. Cent., its rectifying properties are drastically impaired.

(2) Transition region.—In this region the current increases rapidly with applied voltage. The extent of this transition region depends on the properties of the single crystal silicon and the perfection of the alloy junctions. It is governed mainly by the amount of current multiplication near the rectifying junction.

(3) Breakdown region.—As the reverse voltage is increased a region is reached in which the current increases over several orders of magnitude at a constant reverse voltage. It is interesting to note that this breakdown voltage can be controlled by the choice of resistivity of the single crystal material employed in the diode manufacture ; for example, in Fig. 1 type *A* and *B* diodes, which have been produced by the same technique, have breakdown voltages of 250V and 30V, the resistivity of the single crystal silicon being 6 ohm-centimetre and 0·7 ohm-centimetre, respectively.

The breakdown voltage increases with temperature by a factor of less than 0·1 per cent per deg. Cent., although the temperature coefficient is dependent on the single crystal silicon.

In a later section we shall consider the field of application of these low power diodes in power supply.

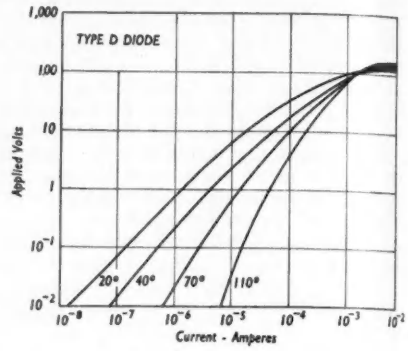
Power Rectifiers

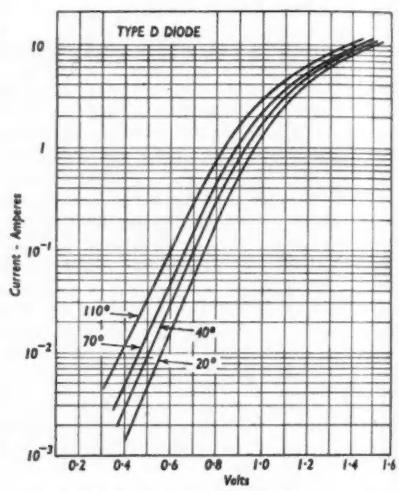
Power rectifiers *D* and *E* in Fig. 1 are by far the most interesting for power supply applications.

Type D.—In Fig. 5 we give the d.c. characteristics and the rectification ratio of a silicon junction diode of area 0·05 square centimetre at various temperatures. The increase in reverse and forward currents in comparison with type *A* diode is due to the different silicon resistivity and the junction area. The rectification ratios for the two diodes are, however, very similar (see Figs. 4 and 5).

(*a*) Forward characteristic.—Power is lost in the junction mainly in the forward direction of current flow. It is thus important to have low values of forward voltage drop. In the diode of Fig. 5 the power loss for 10A at 20 deg. Cent. is 15W. An increase in temperature of 100 deg. Cent. results in a reduction of the order of 6 per cent in this power loss. At a current density of 200A per square centimetre the slope $d(\log V)/d(\log I)$ decreases, the effect previously mentioned in small area junctions.

A similar germanium rectifier has a voltage drop of the order of 0·5V. The larger drop, 1·5V, in the case of silicon is an inherent property of the bulk material. Although this makes the power loss in silicon higher than in germanium, it is compensated by the ability of silicon to withstand higher junction temperatures. The variation of forward characteristic with temperature is similar to that of the small area diodes.





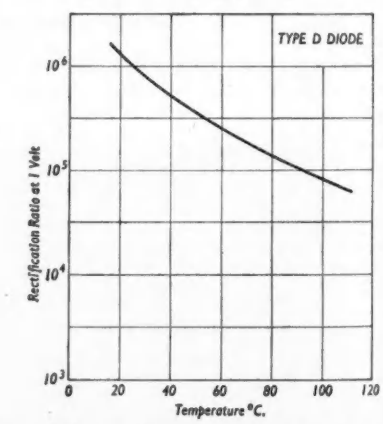
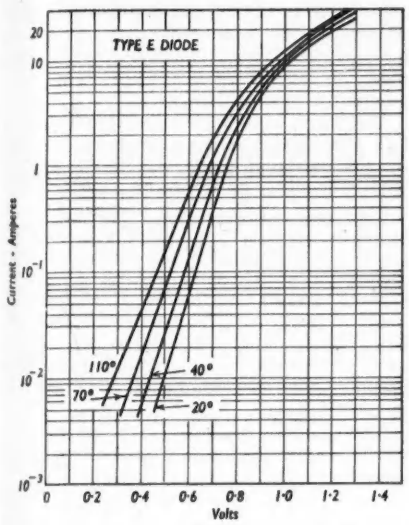


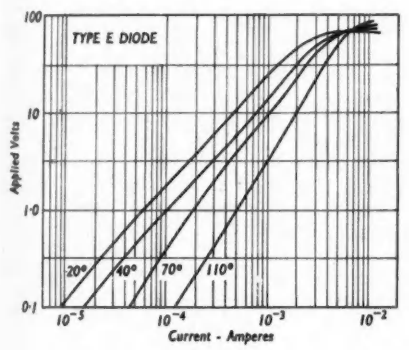
Fig. 5—D.C. characteristics and rectification ratio of a silicon junction diode type D of area 0·05 square centimetre at various temperatures

(*b*) Reverse characteristic.—The reverse currents from Fig. 5, although higher than those shown in Fig. 4, are still sufficiently small for most applications in power rectification. Although the three regions of the characteristic are not distinguishable, the breakdown region, appearing at a lower voltage than in the case of small area diodes made from the same material, still exhibits the property of increase of breakdown

voltage with temperature, which is a useful characteristic when operating these diodes at high temperatures.

Type E.—This diode is similar in its general properties to type *D* and its characteristics are shown in Fig. 6. The increased junction area results in larger forward and reverse currents and in smaller reverse





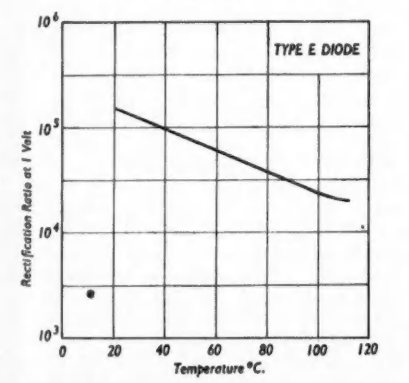


Fig. 6—Characteristics of type E silicon junction diode of area 0·2 square centimetre. The increased junction area results in larger forward and reverse currents and smaller reverse breakdown voltages

breakdown voltages. The junction area in this case is 0·20 square centimetre.

Power Rectifier Junction Temperature.—In the operation of these diodes care has to be taken to ensure that the junction temperature does not exceed a certain critical value, which is, however, difficult to measure. It is clear experimentally that changes in the characteristic above this temperature are irreversible, due to damage of the rectifying junction. Experiment suggests a value of 200 deg. to 300 deg. Cent. in silicon compared with 65 deg. to 80 deg. Cent. in germanium.

Thermal damage is prevented by removal of heat from the junction by forcing air at high velocity through metallic cooling fins attached to the electrodes. The power rating of the diode is then fixed mainly by the efficiency of the cooling fins and the ambient temperature.

Power Rectification in Single-Phase Half-Wave Circuit Producing 1kW

Operation with Natural Convection Cooling.—Type *D* rectifiers assembled with 3in by 3in metal cooling fins have been operated for several hundred hours at 100 peak inverse volts and 10A mean load current, to feed a resistive load. In this experiment the temperature of the cooling fins was 100 deg. Cent. above room temperature. Under these conditions there was no appreciable change in the operational qualities of the rectifier from those at room temperature.

Operation in Forced Air Cooling.—A type *E* rectifier was operated in a similar manner with forced air cooling at a peak inverse voltage of 60V and a current of 25A, corresponding to a mean power output of 1100W. These rectifiers have been successfully operated at ambient temperatures of 100 deg. Cent. It is considered that, by further improvement in the reverse breakdown voltage by using different resistivity material, the power rating of this type of rectifier will be considerably increased.

Applications

In low-current work the diodes described in this paper can be put to two main uses: first as rectifiers of high efficiency and, secondly, as sources of reference potential by making use of the saturation voltage (breakdown region) in the reverse characteristic. In comparison with cold cathode regulating tubes the silicon diodes offer a very much greater range of voltages (from a few volts to several hundred), for which the temperature coefficient is only of the order of 0·06V per deg. Cent.

Silicon power diodes offer the answer to many of the problems of the rectifier engineer. Former methods of power rectification, such as mercury arc, vacuum tubes, mechanical vibrators, selenium cells, copper oxide and germanium cells, offer a range of capabilities suitable for particular applications, none ideal for all purposes.

Silicon rectifiers with the properties of high peak inverse voltage, low reverse current, stability to temperature variation, low forward voltage drop, mechanical simplicity and low material cost promise much in the future.

Acknowledgment

The author wishes to thank Mr. N. R. Howard, who prepared all the single crystal material, and would also acknowledge the many helpful discussions with his colleagues.

References

[1] *Electrons and Holes in Semiconductors*, Shockley, 1950, D. Van Nostrand Company, New York.
[2] Herold, *Journal App. Phys.*, Vol. 5, page 115 (1954).

Assessing Engineering Problems by Operational Research Methods

By M. D. J. BRISBY*

Production and engineering problems which come within the scope of operational research are numerous. This article describes a number of cases where operational research has helped to solve such problems in the iron and steel industry by achieving better co-ordination between men, machines and methods.

THE term operational research was originally coined to describe the activities of a small section of the Air Ministry Research Station at Bawdsey between 1937 and 1939. It has since been adopted widely to denote the scientific approach to the solution of problems involving complex operations. Operational research is not a branch of science like physics or chemistry but a methodology for solving operational and organisational problems—it is, for example, more concerned with the overall problem of running a mill to capacity than with the technical details of the mill drives.

C. Kittel[1] defines operational research as "a scientific method of providing executive departments with a quantitative basis for decisions regarding the operations under their control"; Sir Charles Goodeve[2] calls it, briefly, "quantitative commonsense" and shows how in peace-time it can be directed "to the use of equipment and manpower, to operating procedures, and to the solution of those many problems faced by management in operating or controlling factories or public utilities, or by Government authorities in planning."

Essentially, the aims of operational research are practical—to sum up a situation and to provide a course of action based on the correct appraisal of all available data. Where the complexity of a problem precludes a clear-cut answer, operational research will find the "best bet" using available knowledge. There is much scope for this approach in a wide variety of engineering problems, particularly where the aims are to lower costs, increase production and generally raise efficiency by the better use of men, machines and methods.

* British Iron and Steel Research Association.

Lowering Production Costs

The call to-day for reducing wastage is a challenge which must be met resolutely but with a balanced outlook. The problem is to determine the cost of avoiding wastage and to balance it against the cost of the wastage. Unnecessary delays, breakdowns or off-quality products are obvious points to watch if production costs are to be kept to a minimum. There is no need here for the methods of operational research to make this amply clear.

There are cases, however, where wastage may be unnecessarily high without anyone knowing it to be so. An example is the case of a works that was buying coils of strip nominally 37in wide to slit into six 6in strips for processing. It was known that the width of the coils varied from coil to coil and, therefore, to play safe, the works ordered the coils on the wide side and wasted 3·5 per cent of the total coil weight in "edge scrap." By examining the distribution of a hundred coil widths it was found that to order a nominal width of 36½in, i.e. ½in narrower, would minimise the total amount of scrap which would then amount to 2·5 per cent. Not all the scrap would now be edge scrap, since from time to time there

would be a coil which would not be wide enough to produce six perfect 6in strips and at such times one complete strip would, therefore, have to be scrapped. It is not immediately apparent that by deliberately increasing the risk of occasionally producing a large amount of scrap one will be better off in the long run.

The classic example of this sort of study was done by R. F. Passano[3] on steel works recirculated scrap. He was able to show how the lengths of rolled product could be related to ingot weights and to bloom and billet sizes, pointing to the need for closer control of ingot, bloom and billet dimensions. By greater control in the initial stages of production he was able to reduce the tonnage of " home " scrap by as much as 25 per cent.

Engineering Economics

Frequently the management of a works is faced with the question of deciding whether to buy new equipment, such as a crane, or to " make do " with the old. In such cases usually all that is available is a statement by the engineer on the condition of the crane and a statement by the accountant on the money available. The final decision under these conditions usually goes the way of the best advocate. For a true appraisal of the position management should measure against the capital expenditure for the new crane, the cost of keeping the existing crane in repair and the loss in time and money suffered by the productive department.

A simple example of this kind of " decision-making " issue is the case of a works where opinion was divided on the question of installing a scrap baling press.

It was decided that the answer must be in the value to the steel plant of the extra output from the furnaces which the press would make possible, compared to the cost of running the press.

The factors in the cost balance were the density of the scrap bought by the works, the extent of the furnace charging delays due to the quality of the scrap, the cost of baling scrap and the possible savings to the firm through buying the cheaper pressable scrap. The investigation showed that scrap quality at the works was consistently above the average in the area and that charging delays due to scrap quality were small. The effect of a press on the furnaces would, therefore, have been negligible and with pressing costs in the region of 15s. to 20s. per ton, the installation of a press could not be justified.

At another works a strong case had already been made for a scrap press on the grounds that it would substantially reduce furnace charging times and so achieve the desired effect of raising the output of the steel plant. The magnitude of charging delays depends on numerous factors, among which are the charging rate aimed at, the incidence of furnace " bunching " (which is calculated on the basis of probability theory), the magnet crane and charger capacities, the range of scrap densities, the number of pans available for carrying scrap, their turnround time and the organisation of the shop. If all these factors are known quantitatively, the resulting charging delay can be calculated. If, next, one or more of these factors determining bunching delays are varied and the calculations repeated, the effect on charging time of adding to the equipment of the shop, or of changing its methods of working, can be determined. On this basis it was possible to show that if all suitable scrap as pressed the mean charging delay would have been reduced by about half-an-hour, but that if other and less costly measures were taken such as improving the organisation of the scrap shed and rationalising the charging sequences, resulting increase in steel output would more than match the benefits to be gained by installing a press. The outcome of the study was that the press was not put in, and that the money was made available for more essential modifications to the layout of the shop.

Increasing Production

Increasing the output of a plant generally involves studying the incidence and causes of delays and the throughput capacities of the various units in the production line. A typical example is the study of a rolling mill where it was necessary to increase the output of the mill to keep pace with the recently enlarged capacity of the steel plant. A conventional time study showed that no time was lost in rolling operations and that output could not be increased by greater effort on the part of the mill operators. It was found, however, that the mill was occasionally held up for two reasons beyond the control of the mill crews : first, because ingots did not always arrive at the roller table when wanted, and, secondly, because the cogging mill (which operated in series with a billet mill) was at times held up by the billet mill.

Observations showed that ingots were called for at evenly spaced intervals, whilst they came from soaking pits which varied in distance from a few feet to some 200ft, and that if proper allowance was made for travel times, some 4 per cent increase in throughput could be expected. A study of rolling times on the two mills showed that these were not ideally matched and that, by suitably changing the transfer bloom sizes, the throughput of the two units could be balanced more nearly. This involved modifying the rolling schedules on the cogging mill to produce a range of optimum bloom sizes for breaking down to specific billet sizes. It was estimated that the better matching would yield a further 5 per cent throughput.

The reverse problem occurred in a works which had recently installed a new rolling mill with a capacity substantially larger than the output of the melting shop. It was generally believed that the chief obstacle in the way of higher ingot output lay in the inadequate handling facilities. A study of cast histories showed that this was only partially true and that the short charging periods did not, under existing conditions, lead to higher output rates, and that the long charging times obtained could not be accounted for by delays in the supply services alone. It followed, therefore, that unless the furnaces and steel-making practice could be improved, bringing materials to the furnaces more quickly would not necessarily lead to increased output.

With these facts established it was possible to focus attention where it was most needed, i.e. on the modifications to the furnaces and steel-making practice which would enable the furnaces to benefit by faster charging.

Congestion Problems and Plant Capacities

Congestion arises because the rate at which events occur is greater than that at which they can be dealt with. This is just as true of ideas and paperwork as it is of traffic in the London rush hour ; of crowds coming away from a football match as it is of machines coming off an assembly line.

It is the variability of demand that gives rise to the problem, because if capacity is sufficient for peak demand there must be periods when there is excess capacity when demand is slack.

All operations involving movement of materials are subject to congestion if disposal facilities do not match arrival rates. In the most general terms there must be matching of capacities at all stages in the production line. This does not mean to say that all throughput rates must be equal—obviously this cannot be so in a complex sequence of operations involving continuous and batch processes—but the system as a whole, including both handling and storage facilities, must be capable of dealing with all commodities as fast as these arise.

It is worth going to considerable trouble to find the correct balance between handling or pipeline facilities on the one hand, and storage facilities on the other, as it provides a guarantee against congestion and is an essential factor in minimising production costs.[4] It is obviously both undesirable and uneconomical to have sidings or blast-furnace bunkers large enough to hold a shipment of iron ore. The solution must be to have sidings large enough to absorb the temporary impact of train arrivals while surplus materials are being discharged to stockyard.

The general principle involved may be simple, but the quantitative solution is often complex. The need for storage sidings is obvious, but how big should these be ? The answer demands a knowledge of the pattern of train arrivals, of the real cost of holding materials in wagons, and of unloading and reloading costs. Only then is it possible to find the most economical size of sidings, based on the cost balance between holding materials in wagons and discharging these to ground.[5, 6]

An example of congestion arising due to lack of matching in the capacities of two consecutive production departments is the case of blast furnaces delivering hot metal to a steel plant. The complaint in the ironworks was that the slow return of hot metal cars caused inconvenience to the blast-furnace department and, at times, delay to furnace tapping, whilst the steel works felt that all troubles would come to an end if the ironworks would buy more hot metal cars.

The problems experienced in this case were those inherent to batch processes and common to all transport systems. Blast furnaces, although operated continuously, deliver hot metal in batches of varying sizes and at somewhat irregular intervals. Demand for hot metal at the steel plant is also in batch quantities, of varying amounts and at irregular intervals. But because these two units are rarely in phase, and then only by chance, some form of storage capacity must be provided. Storage, in such a system, can only take the form of pig casting machines in ironworks, or " mixers " in steel works. If ironworks and steel works are properly balanced, temporary discrepancies between their capacities will be absorbed by the mixer in the steel plant, pig casting being resorted to only in cases of emergency.

The investigation showed up certain inefficiencies in the traffic department, but the real trouble was found to be the storage capacity of the mixer which was not sufficient to balance the fluctuating difference between the production rates of the blast furnaces and the consumption rates of the steel plant. The remedy was suggested by studying the distributions of hot metal consumption and production rates at the steel plant and at the blast furnaces in conjunction with the pig caster and mixer capacities. The degree to which trouble was experienced depended on the frequency with which the peak

demands at the steel furnaces coincided with the troughs at the blast furnaces, on the time for which this condition persisted and on the magnitude of the gap between production and consumption tonnage rates. Better communications between the two departments and an attempt to forecast steel plant requirements and ironworks production did much to improve the situation.

Forecasting Situations and Plant Requirements

Operational research can be of great assistance in helping to solve problems which involve an element of chance. Generally, these can be classed into two groups ; (i) those involving straight forecasts based on probability theory—for example, forecasting the number of furnaces in a melting shop which may tap, say, in any one hour period, and (ii) those involving a forecast of events when basic conditions change, such as forecasting the equipment required to cope with an increase in production.

Typical of the first group are the studies, already mentioned, of " bunched charging " in open-hearth melting shops,[7, 8] where the analysis of the probabilities of more than two, three or four furnaces requiring to be charged at any one time has provided useful information on plant and stock requirements, both for normal and emergency working, and on standards of performance to be demanded from crane and traffic services.

Typical of the second group is a study which was undertaken at a steel works in the course of construction, where management required to forecast the facilities which would ultimately be needed to ensure the adequate supply of materials to a larger number of furnaces than were in use at the time. A study of the conditions prevailing, combined with work on the mathematical formulation of the effects of congestion, made it possible to forecast the conditions which would obtain with all furnaces in commission. On this basis, it was possible to determine both the equipment and standards of operation which would be required to run the enlarged melting shop efficiently.

Another example is that of a works where a contemplated change in the position of a stockyard involved bringing materials into the works through a new entrance and using new reception and holding sidings. The change meant carrying materials to the production units over a very busy works line. The problem here was to decide whether the existing rail system could cope with the proposed re-arrangement of the internal traffic. A study of the line occupation showed that the line was less congested than it was believed to be. By plotting actual train movements, it was possible to show how additional trains could be fitted into the traffic system without imposing too heavy a load on the line or on the locomotives.

Production Control

Production control fulfils two important functions—it makes it possible to keep a close check on all operations in a production line and it provides a basis on which to plan future production.

The first function of production control is to facilitate the smooth operation of a shop by seeing that orders are dealt with in proper sequence, that all raw materials are available when wanted, that these are processed on the correct machines, in the correct order, that they are passed for quality, and finally, are ready for despatch on the correct date. By keeping a tab on all operations, production control can be used to gauge progress through the shop. It can be made to provide a weekly, daily, or even hourly check on flow ; as such, it is a valuable means of showing up inefficiencies of men, machines and layout.

The second function of production control is to enable management to plan production in the best possible way, to fix priorities to meet delivery dates, to utilise all machinery and equipment to best advantage, and this at the lowest possible cost consistent with customers' requirements. For works producing a wide range of commodities for a large number of customers, a truly efficient production control scheme is of the first importance.

The work so far undertaken at several firms, has concentrated on the organisational aspects of improving control on operations and on reducing paperwork—a rewarding line of study, particularly in some of the older works. There is obviously nothing new in this, but it can be claimed that the methods of operational research are particularly well-fitted to analyse production and planning data, to find inefficiencies and to establish the best course of action to be taken in the light of facts—technical, organisational and economic.

Acknowledgments

Especial acknowledgments are due to Mr. R. Solt, Mr. W. O. Pendray and Mr. R. H. Hannaford, who undertook the greater part of the researches described. Acknowledgments are also due to Mr. R. W. Davis, now with the British Iron and Steel Federation.

References

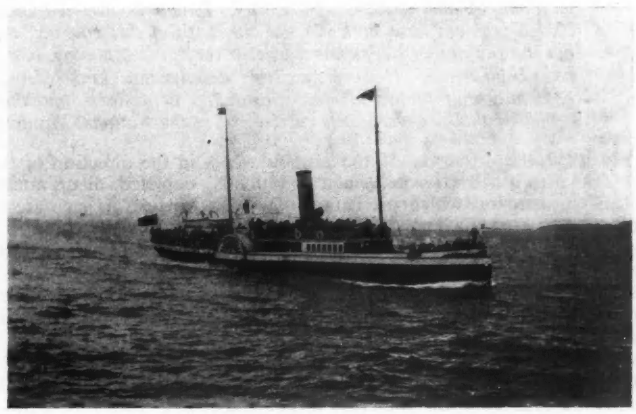
[1] C. Kittel : " The Nature and Development of Operations Research," *Science*, 1947, 105, February 7th.
[2] Sir Charles Goodeve : " Operational Research," *Nature*, 1948, 161, March 13th, 377.
[3] R. F. Passano : " Finished Steel Production : Possible Increase from Existing Equipment," *Yearbook Amer. Iron and Steel Inst.*, 1949, 192.
[4] R. Solt : " Capacities in a Manufacturing Process," *Operat. Res. Quart.*, 1954, 5, March, 24–26.
[5] M. D. J. Brisby and R. T. Eddison : " Train Arrivals, Handling Costs and Storage of Raw Materials," *J.I.S.I.*, 1952, 172, October, 171–183.
[6] M. D. J. Brisby : " Traffic Congestion in Iron and Steel Works : Causes and Remedies," *Iron and Coal Trades Review*, 1954, 169, November 5, 1103–1109.
[7] R. Solt, " Charging Delays Due to Furnace Bunching (A Method of Assessment)," *J.I.S.I.*, 1955, 179, March, 260–264.
[8] M. D. J. Brisby and W. O. Pendray : " The Supply of Scrap to Open Hearth Furnaces," *J.I.S.I.*, 1955, 179, March, 252–260.

Passing of the last Paddle Cargo Steamer " Lord Elgin "

By G. W. TRIPP, O.B.E., M.I.C.E.

On May 11th the last British paddle cargo steamer sailed for the last time between Southampton and Cowes, and so terminated another phase in the story of the paddle boat. In May, 1881, there appeared on the South Coast a smart little excursion steamer acquired by the Bournemouth, Poole and Swanage Steam Packet Company, who advertised this " fast and magnificent saloon steamship " as the " largest and fastest steamer on the south coast." " Lord Elgin " was actually built in 1875 by Richardson Duck and Co., of Stockton, and had a length of 160ft, breadth of 20ft, depth 6·8ft, tonnage 203 gross. Her engines were supplied by T. Richardson and Sons, of Hartlepool, and were of the two cylinder diagonal design, her cylinders having diameters of 22in and 42in respectively, and a stroke of 42in. Her " fast" speed was of the order of 12 knots.

A pretty and well-proportioned steamer with red funnel and white deck houses she became popular, but after competing for some time with existing lines, she then sailed in partnership with steamers operated by Messrs. Cosens, of Weymouth, settling down to help in maintaining the frequent sailings between Bournemouth and Swanage in



Paddle steamer " Lord Elgin " as a passenger boat

company with a Cosens steamer. When sailing on her in 1905 the writer was impressed by her pleasing lines in comparison with her competitors.

She next was acquired in 1908 by the rival Southampton, Isle of Wight and South of England Royal Mail Steam Packet Company, but for a considerable time she was left on the same service, until she was outclassed by newer tonnage. Her owners then decided on the bold expedient of converting her to a cargo steamer, and all her passager accommodation was ruthlessly removed and her decks cleared, while her erstwhile dining saloon was converted to a cargo hold, her pole masts were removed and were substituted by a single mast abaft the funnel, equipped with a loading derrick, and then, season after season, year in, year out, she left Southampton shortly before noon and with a very heterogeneous cargo she made the passage to Cowes in about seventy minutes returning later in the afternoon. Sometimes in the summer she made additional crossings with motor-cars.

In crossing on her as a cargo steamer recently the author was struck by the great variety of merchandise carried, including a van, a railway container, coffins, baulks of timber, steel piping, and a great variety of small packages. There were still signs to remind him of the hey-day of her popularity, even though probably she was a better dividend earner as a cargo steamer than ever as a pleasure steamer.

After eighty years an honourable life has to end, but she will long be missed on Southampton Water. We illustrate her as she was as an excursion steamer in 1905. In an article on " Cross-Channel and Coastwise Cargo Ships "* her portrait as a cargo steamer appeared.

Improved Dockside Gangway.—We have received particulars of an improved dockside gangway developed by Whittingham and Mitchel, Ltd., and built of aluminium alloys supplied by the British Aluminium Co., Ltd. The gangways are available with self levelling steps, or with flat floor and hardwood or extruded aluminium treads. For the articulating system the steps are of strong box form with aluminium castings housing twin articulating bars attached to the step-ends. The gangway has solid side webs, " Z " section cross bracing below the steps, and a gangway 42ft long with a clear inside width of 3ft weighs 12 cwts.

* The Engineer, March 30, 1951, page 402

Wind-Excited Oscillations of Tall Stacks

By C. SCRUTON, B.Sc., A.F.R.Ae.S., A.F.I.Ae.S.

The problem of the oscillating stack is one of a group of similar problems in aerodynamic stability which includes suspension bridge oscillations and the galloping of electric transmission lines. Extensive investigations of the suspension bridge problem have been carried out, both in this country[2] and in the U.S.A., but the swaying of stacks has attracted very little attention, and few investigations have been made. However, existing aerodynamic knowledge provides a simple explanation of the aerodynamic instability of a stack, and this is supported by some model experiments carried out at the National Physical Laboratory.

IN 1952 the attention of the author was drawn to a newly erected stack of welded steel construction which oscillated in winds of quite low speed. The stack concerned has a circular section of 4ft diameter (except near the base) and is 150ft high. It was unstayed at the time when the oscillations occurred. Eye-witness accounts estimated amplitudes of several feet at the top of the stack, and although these were not sufficient to cause failure, they were the cause of considerable anxiety to the engineers responsible and to the staff working on the site. There are reports of similar incidents in the United States, and reference is made to some of them by Den Hartog.[1] In all instances reported the stacks involved were of welded steel construction ; in one, failure occurred and partial dismantling of the stack was necessary. Den Hartog concludes that large welded steel stacks are unsafe, and that dampers or other means of suppressing the oscillations are essential.

But while there remain several aspects of the problem requiring further investigation before the behaviour of a stack in wind can be predicted in the design stage, it is believed that the account which follows will be of interest to engineers generally as well as to designers of stacks and other outdoor structures of similar form.

Fig. 1—Vortex formation behind a flat plate

The Mechanism of Instability

An explanation of how instability arises requires a knowledge of the airflow pattern generated by a cylinder of bluff section. The general nature of this flow is well-known and is adequately described in text books on aerodynamics.[3] When air flows over a cylinder vortices are generated and then detached in succession first from one side of the cylinder and then from the other, and are carried downstream. The photograph reproduced in Fig. 1 illustrates the instantaneous flow pattern† as seen by a stationary observer. The discrete vortices would be seen more clearly by an observer moving with the stream. The receding cylinder would then appear to leave behind a double row of evenly spaced staggered vortices moving only slowly away in the direction of the cylinder. The flow is depicted diagrammatically in Fig. 2. The vortices in each are of equal strength but are of opposite rotation. Such a vortex pattern is known as a vortex street or, alternatively, as a Kármán vortex trail. The frequency of generation of a pair of complementary vortices (i.e. one in each row) has been measured by several investigators for a variety of cylindrical shapes. It is expressed non-dimensionally in the form

$$S=\frac{f.D}{V} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where

S is known as the Strouhal number.
f is the frequency of shedding of vortex pairs.
D is the projected depth of the cylinder in the direction of the air flow.
V is the speed of the fluid.

In general the value of S depends on the cylindrical shape and on the Reynolds number R, where $R=\frac{VD}{\nu}$, and ν is the kinematic viscosity of the fluid. For bluff bodies with sharp edges such as flat plates with faces normal to the wind direction, triangular or square sections, &c., the experimental evidence is that the value of S is about 0·15 and is independent of R ; for rounded shapes such as circular cylinders, the values of S show greater dependence on Reynolds number. Fig. 3 gives the results of some measurements by Relf and Simmons[4] of the eddy frequency in the wakes of circular cylinders. The value of S remained at nearly 0·20 for the range $10^3<R<2\times10^5$. Above this range the flow was aperiodic. Den Hartog,[1] however, on the evidence of some observed smoke-stack oscillations suggests that the limiting value for periodic flow extends at least to $R=7\times10^6$.

In the development of the vortices the cylinder is subject to drag forces and to forces in a direction transverse to that of the wind. The latter may be regarded as the "lift" effects due to changes in circulation round the cylinder necessary to balance the vorticity shed into the wake. Since the alternate vortices are of opposite sign a periodic transverse force results of frequency equal to that at which each pair of vortices is shed from the cylinder. When this frequency coincides with a natural frequency of the structure, a resonance oscillation will tend to build-up. Experiments on a model stack, which will be described in the next paragraph, confirmed that oscillations start at a wind speed when the eddy frequency, as determined by the Strouhal relation for a stationary stack, agrees with the stack frequency (see Fig. 4). They also showed that the stack oscillations continued for a range of wind speed beyond which this agreement holds. Since the oscillation frequency did not change it is reasonable to assume that the vortex frequency remained constant while the oscillations persisted. This result leads to the conclusion that the cylinder oscillations themselves must be able to control the rate of vortex shedding for a certain range of wind speed. Steinman[5] cites some experimental observations which showed that when a cylinder oscillates the eddies are shed at or near each end of the amplitude range. The normal width (h, Fig. 2) of the vortex wake is increased from that of the stationary cylinder by the double amplitude. The effect is to increase the calculated lateral force in the ratio $(h+2a)/h$ and to reduce the eddy frequency in the inverse of this ratio so that

$$S_a=\frac{h}{h+2a}.S \quad . \quad . \quad . \quad . \quad (2)$$

where S_a is the Strouhal number for amplitude a. From this Steinman[5] derives an expression for the cylinder amplitude which appears to be in general qualitative agreement with observation. Maximum amplitudes were found to occur at a wind speed about 1·45 times greater than the critical wind speed for the onset of oscillations.

Model Experiments

The notation used is as follows :—

V_c is the critical wind speed for maintained oscillations.
N is the frequency of oscillation.
D is a typical dimension usually taken as the diameter for a circular stack.
M is the mass per unit length.
t is the thickness of the stack wall.
σ is the density of the constructional material.
ρ is the density of the fluid.
δ is the logarithmic decrement defined as the natural logarithm of the amplitude ratio of successive cycles of oscillation.

$$=\frac{2\cdot303}{NT}\log_{10}\frac{A_0}{A_1},$$

where T is the time taken for amplitude A_0 to decay to A_1.

Subscripts m and f are used to denote model and full-scale values of the above quantities respectively.

Although the model experiments described were made to provide data in connection with the aerodynamic oscillations of the particular steel stack mentioned in the opening paragraph, the results have a wider application and significance. The full-scale stack is of welded steel construction with wall thicknesses graded as follows :—

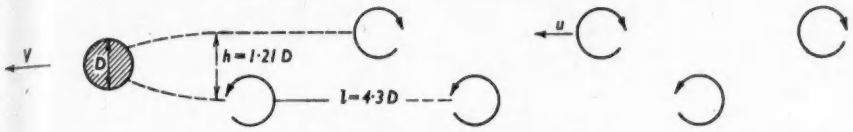
Distance from base, ft	0 to 48	48 to 75	75 to 150
Wall thickness, in	½	⅜	⅜

The outside diameter of the stack tapers

* Communication from the National Physical Laboratory.

† The photograph is that of the wake behind a flat plate in a current of water, made visible by the injection of a stream of air bubbles. The flow behind a circular cylinder is of similar pattern.

linearly from 10ft at the base to 4ft at a height of 39ft. From this height upwards the diameter remains constant at 4ft. The base of the stack is bolted by a flange to a ring embedded in a substantial concrete block. Measurements of N_F and δ_F were made on the site. Because of cut-outs to accommodate a branch vent and an inspection door, the



u, is the velocity of the vortex system$=0\cdot14V$

$$f=\frac{V-0\cdot14u}{4\cdot3D}=0\cdot20\frac{V}{D}$$

Fig. 2—Vortex street in wake of circular cylinder

values differed slightly according to the direction of the oscillations. The average values found were :

$$N_F=0\cdot92 \text{ c/s.}$$
$$\delta_F=0\cdot010.$$

A 75in length of aluminium tube, of diameter 2in and wall thickness $\frac{1}{16}$in, provided a simple but adequate 1/24-scale of the stack, the tube being clamped at one end to the floor of a wind tunnel. When the influence of wind speed on the oscillation frequency is small, as in the present instance, the conditions for dynamic similarity between model and full-scale structure simplify considerably. It can be shown[6] that values of the non-dimensional ratio V_c/ND is the same for model as for full-scale oscillations, provided their external geometric shapes are similar, and the ratio $M\delta/\rho D^2$ has the same value for model as for full scale. For a stack the

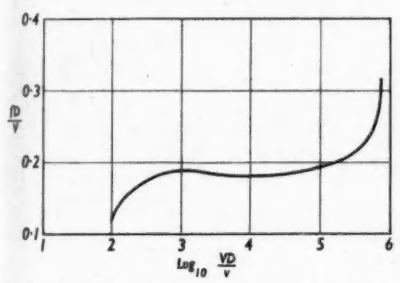


Fig. 3—Variation of the frequency of vortex-shedding with Reynolds number

latter ratio can be more conveniently expressed as $\sigma t\delta/\rho D$. For tests in an atmospheric wind tunnel $\rho_m=\rho_f$, and the above ratios yield

$$\left.\begin{aligned} V_f&=V_m\cdot\frac{N_f}{N_m}\cdot\frac{D_f}{D_m}\\ \delta_f&=\delta_m\cdot\frac{\sigma_m}{\sigma_f}\cdot\frac{t_m}{t_f}\cdot\frac{D_f}{D_m}\end{aligned}\right\} \quad . \; . \; (3)$$

The grading of the wall thickness of the actual stack was not represented on the model. Since t arises in the above expressions from inertial considerations, and not from those of stiffness, very little error is introduced if the value of t is assumed to be $\frac{5}{16}$in for the entire height. The frequency of the model stack was 13·35 c/s and on substitution of the numerical values

$$\left.\begin{aligned} V_f&=1\cdot65_5V_m\\ \delta_f&=1\cdot66_5\delta_m\end{aligned}\right\} \quad . \; . \; . \; . \; (4)$$

In the experiments the value of δ_m was increased by binding the lower half of the tube with surgical bandage carrying a quantity of a mix of plaster of Paris in water. When the plaster had set and dried it formed a hard casting of between $\frac{1}{32}$in and $\frac{1}{16}$in thickness. The height of the coating was gradually reduced to give lower values of δ_m. The addition of this damping coating made very little difference to the natural frequency.

For each value of δ_m the behaviour of the model stack was observed as the wind speed was gradually increased and the critical speeds bounding speed ranges for maintained oscillations were measured. In the plot of the results shown in Fig. 4, all dimensional quantities quoted have been converted to refer to the particular full-scale stack by the relations (4). The non-dimensional values, of course, are applicable to any stack of similar geometric configuration to the model. The following results are of interest :—

(1) The oscillation frequency in wind differed very little from that in still air.

(2) At all values of the structural damping the oscillations started at a wind speed when the eddy frequency, as calculated for the stationary circular cylinder, equalled the natural frequency of the stack, and they persisted for a range of wind speed dependent on the damping. This range extended to approximately twice the lower critical speed when $\delta_f=0$, but the upper bound for instability decreased linearly with increase of δ_f until at $\delta_f=0\cdot07$ the instability was suppressed.

(3) The amplitude of the oscillations decreased with increase of damping.

(4) An approximate estimate of the lower critical wind speed at which oscillations of a stack of circular section will tend to be maintained if the damping is sufficiently low can be obtained from substitution in

$$V/fD=5.$$

This requires a knowledge of the lowest natural frequency of the stack. A method for calculating this frequency is described in the Appendix.

Preventive Measures

It is evident that oscillatory tendencies of stacks in wind may be influenced by modifications to the aerodynamic shape of the structure, and may be reduced by an increase of structural damping, and by an increase of the natural frequencies. Effective modifications to the aerodynamic shape are difficult to achieve when it is necessary to provide against winds from any direction. It is highly probable that devices attached to the stack to break up the continuity of the airflow along its length would reduce the tendency to oscillate, but they would also be very unsightly. When the relative wind direction does not vary, as with a moving cylinder in a still fluid, modifications to the cylinder shape are more practicable. Steinman,[5] for instance, mentions the use of guide vanes for stabilising submarine periscopes. The provision of additional structural damping is perhaps the easiest application in practice. It may be feasible to add sufficient damping by coating the stack with a damping material as in the model experiments. Such a coating is, of course, most effective when applied at positions of highest bending curvature. The damping properties of the material used must not deteriorate with time. Deterioration might arise from cracks developing in the material, or because the material fails to adhere to the surface. An alternative way of introducing damping and one which is reported to have proved successful in the United States is to incorporate damping devices in stays attached to the stack. The oscillations of the steel stack discussed in this note have been successfully suppressed by fitting loose stays at one-third and at two-thirds of the height. These stays were deliberately left slack, and it is highly probable that the measure is successful because the stays provide some form of impact damping, rather than because they increase the natural frequency to such an extent that the critical wind speed is higher than the maximum experienced at the site.

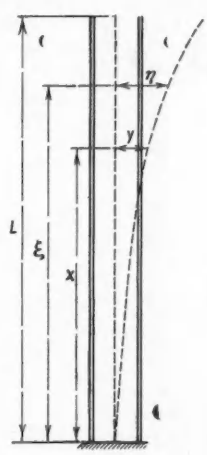


Fig. 5

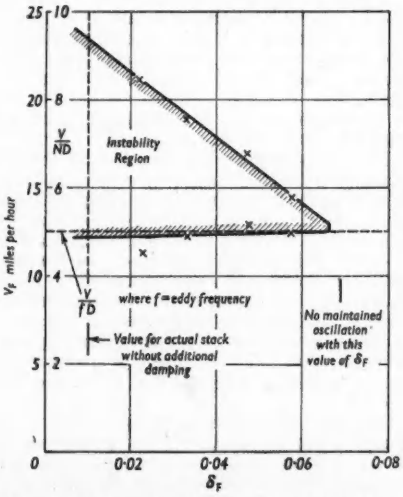


Fig. 4—Aerodynamic stability of a steel stack of circular section

Acknowledgments

The work described above was carried out in the Aerodynamics Division of the National Physical Laboratory on behalf of the Engineering Division of the Ministry of Works. This paper is published by permission of the Director of the Laboratory and with the approval of the Chief Mechanical and Electrical Engineer of the Ministry of Works.

Appendix

The Lowest Natural Frequency of a Self-Supporting Steel Stack

The lowest natural frequency of a self-supporting stack can be calculated to a sufficient accuracy by Rayleigh's method.

When the stack is displaced sideways there is an increase S in the strain energy of bending and a reduction C in the compressive energy, due to the downward displacement of the stack. These may be expressed as (see Fig. 5) :

$$S=\tfrac{1}{2}\int_0^L EI\left(\frac{d^2y}{dx^2}\right)^2dx=\tfrac{1}{2}\int_0^L\frac{M^2}{EI}dx \quad . \quad (1a)$$

$$C=\tfrac{1}{2}\int_0^L\left(\frac{dy}{dx}\right)^2\left(\int_x^L w\,d\xi\right)dx \quad . \quad . \quad . \quad (2a)$$

where w is the weight per unit length of stack. The maximum kinetic energy of the stack during an oscillation of frequency N is given by

$$K=\tfrac{1}{2}\int_0^L\frac{w}{g}\cdot p^2y^2dx \quad . \quad . \quad . \quad . \quad . \quad . \quad (3a)$$

where $p=2\pi N$.

The balance of energy during a cycle is expressed by

$$K=S-C \quad . \quad . \quad . \quad . \quad (4a)$$

Equation (4*a*) can be used to evaluate the frequency provided the EI and w distributions and the deflection mode are known.

Example.—As a simple example assume a uniform distribution of EI and w, and also assume the oscillation mode to be of the same shape as that of a cantilever beam bending under its own weight. Then

$$y=k\left(\tfrac{1}{2}L^2x^2-\frac{1}{3}Lx^3+\frac{1}{12}x^4\right) \quad . \quad . \quad (5a)$$

and thus

$$S=\frac{k^2EIL^5}{10}$$

$$C=\frac{wk^2L^8}{80}$$

and

$$K=\frac{13}{1620}\cdot\frac{w}{g}\cdot p^2k^2L^9,$$

and on substitution in (4*a*),

$$N=0\cdot560\sqrt{\frac{EIg}{wL^4}-\frac{1}{8}\frac{g}{L}} \quad . \quad . \quad (6a)$$

It may be noted that when the gravitational forces are not effective, as for a horizontal beam,

$$N_0=0\cdot560\sqrt{\frac{EIg}{wL^4}} \quad . \quad . \quad . \quad . \quad (7a)$$

which is the usual formula for such a beam.

For the critical condition yielding $N=0$

$$(wL)_{cr}=\frac{8EI}{L^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8a)$$

and this corresponds quite closely to the usual expression for the critical load for buckling,

$$(wL)_{cr}=\frac{7\cdot83EI}{L^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9a)$$

The small difference must arise from differences in the deflection modes assumed for oscillations and for buckling.

Equation (6*a*) can be written

$$N=N_0\sqrt{1-P/P_{cr}} \quad . \quad . \quad . \quad (10a)$$

Here

N is the stack frequency.
N_0 is the frequency if the stack is assumed to be horizontal.
$P=wL$.
P_{cr} is the critical load for buckling.

REFERENCES.

[1] J. P. Den Hartog : "Recent Technical Manifestations of van Kármán's Vortex Wake," *Proc Nat. Acad. Sc. of U.S.A.*, Vol. 40, No. 3, 1954.

[2] C. Scruton : "An Experimental Investigation of Aerodynamic Stability of Suspension Bridges with Special Reference to the Proposed Severn Bridge," *Proc. I.C.E.*, Part I, March, 1952.

[3] S. Goldstein (Editor) : "Modern Developments in Fluid Dynamics," Vols. I and II, Oxford University Press.

[4] E. F. Relf and L. F. G. Simmons : "The Frequency of the Eddies Generated by the Motion of Circular Cylinders Through a Fluid," A.R.C. R.& M., No. 917, 1924.

[5] D. B. Steinman : "Problems of Aerodynamic and Hydrodynamic Stability," *Proc. Third Hydraulics Conference, Bulletin* 31. Univ. of Iowa Studies in Engineering, 1947.

[6] C. Scruton : "An Experimental Investigation of the Aerodynamic Stability of Suspension Bridges," *Prelim. Pub. for the Third Congress* (1948), *Inter. Assoc. Bridge and Struct. Engng.*

Roosecote Power Station

ON June 2nd, Roosecote power station was officially opened by Sir Henry Self, Deputy Chairman (Administration) of the Central Electricity Authority. This station has a capacity of 120MW and occupies a 110-acre site near Cavendish Dock, Barrow-in-Furness, Lancs. Design work was begun in 1947 on behalf of the Corporation of Barrow, and the construction was undertaken as part of the Central Electricity Board's 1951–52 programme.

Site.—Included in the area are about 40 acres of salt marsh, which lay at 12ft to 14ft above O.D., as well as undulating land up to 50ft above O.D. The high ground provided material for raising the marsh area and for filling the banks of the ash ponds, which occupy some 45 acres. In the course of reclamation 250,000 cubic yards of fine sand and gravel were moved to bring the lower levels to 20ft above O.D.

Trial borings revealed that the subsoil to a considerable depth consisted of layers of sand, gravel and clay with occasional boulders of hard rocks. As a consequence the use of piles for the foundations became necessary.

An 18ft wide access road was constructed from Rampside Road, about ½ mile to the east. A single-line railway which already existed at the north end of the site was later extended into the coal siding system.

Cooling water is obtained from Cavendish Dock, thus saving elaborate intake works, which would otherwise have been necessary because of the existing mud flats and the large tidal differences. Feed water is supplied from the town main.

Foundations.—For the main and ancillary buildings and plant a total of 4220 "Franki" reinforced concrete piles, 16in diameter by 30ft long, were driven. These were manufactured on site, while for the support of the pumping station at Cavendish Dock and of the four 60in diameter pipelines 459 precast reinforced concrete piles, 14in by 14in by 30ft, were used. In the main building heavy reinforced foundation blocks carry the steel columns, turbo-alternators and boilers, and between them are the reinforced concrete culverts for the condenser cooling water also on piles. The remainder of the basement floors rests on a pile-supported reinforced concrete raft.

Our first illustration is a view of the power station from the west, the lower portion of the main building being the turbine hall, with conveyor and boiler-house to the right of it, followed by the precipitators and chimneys. On the left may be seen the workshop, and behind it and connected with the turbine building by a footbridge is the administration block.

The buildings have riveted steel frames with plated box columns resting on slab bases. Dimensions of the turbine hall are 252ft long, 94ft wide and 68ft high. The boiler-house is 235ft long, 102ft wide and 116ft high. A total of 3200 tons of steel was used for the frames. Each of the four coal bunkers is of steel plate, lined with "Gunite" and holds 570 tons of coal.

Externally the main buildings are clad with brown rustic facing bricks with copings, sills and canopies in limestone-based artificial stone. Pressed facings washed with coloured washes are used inside. The plain twin chimneys are also faced with brown rustic bricks and lined with acid-resisting bricks. Each weighs 3500 tons and stands 300ft high, the inside diameter at the top being 14ft. They are supported on concrete bases 12ft thick and constructed in three hexagonal tiers, the bottom tier being 52ft between sides and the top tier 34ft. The bases in turn rest on 324 piles.

Turbo-alternators.—The turbine hall, shown in our second illustration, is equipped with four 30MW turbo sets, which have an economic rating of 24MW. In the turbine high-pressure cylinders there are twenty-three impulse stages, and in the low-pressure cylinders there are six double-flow impulse stages. Steam conditions are 600 lb per square inch gauge and 850 deg. Fah. at inlet, with bleed-off for final water heating at 157 lb and 49 lb per square inch absolute from the high-pressure stage, and 14·4 lb and 3·6 lb per square inch from the low-pressure stage. Each turbine exhausts at 1·3in Hg. absolute to a three-pass two-shell condenser rated at 168,000 lb of steam per hour. Design inlet temperature of the cooling water is 65 deg. Fah., design outlet temperature is 80·5 deg. Fah.

There are two electrically-driven extraction pumps to each machine, each capable of handling the full quantity of condensate. Two steam jet air injectors are fitted to each condenser, each of 100 per cent capacity, and in addition there is a quick-start ejector taking twenty minutes to reach the rated vacuum.

Feed water is supplied to the boilers at a maximum temperature of 345 deg. Fah. by six electrically-driven pumps, each rated at 100 per cent, with four steam-operated standby pumps rated at 50 per cent.

The alternators are rated at 37,500kVA each and generate current at 11,800V, three-phase, 50 c/s (3000 r.p.m.) Each alternator is air cooled by two fans mounted on the rotor shaft

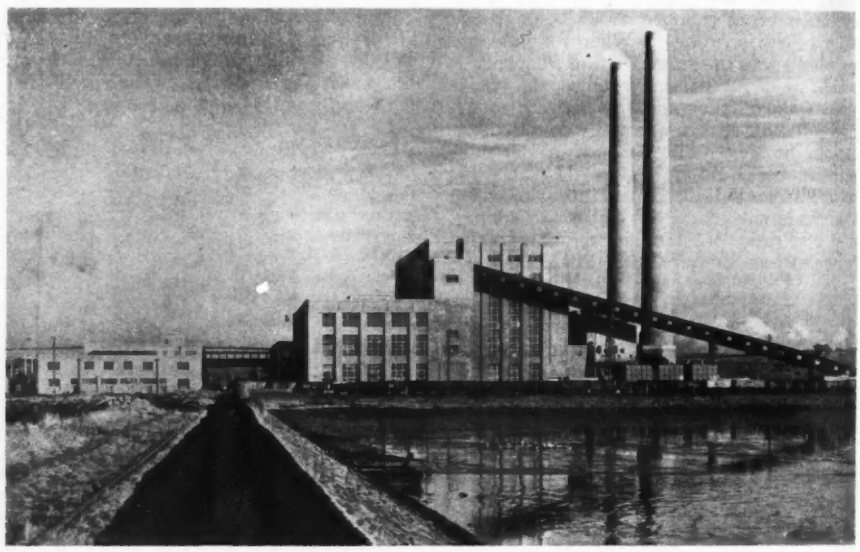


Fig. 1—Roosecote power station from the west

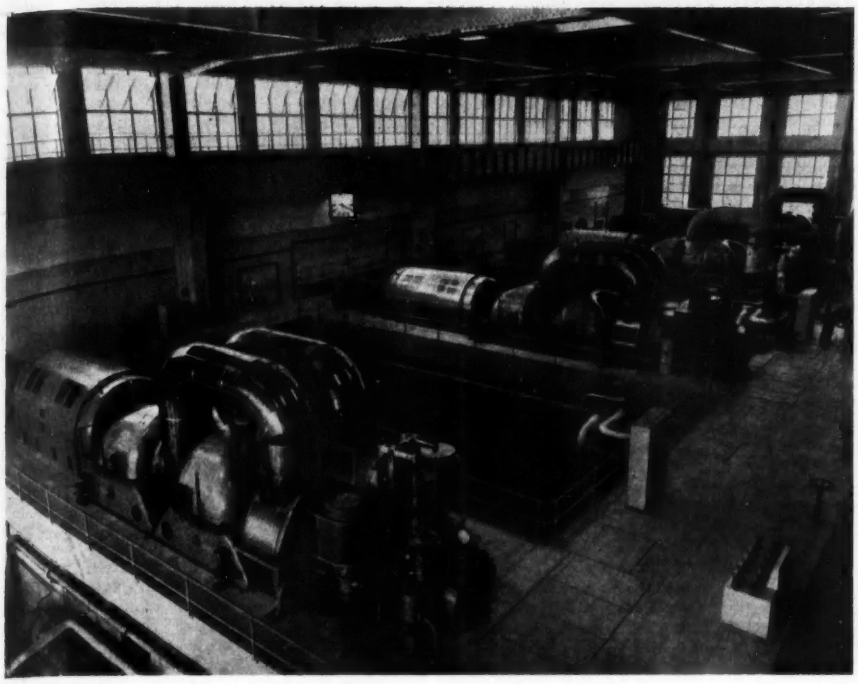


Fig. 2—Turbine hall, showing the four 30MW turbo-alternator sets

and rated at 50 per cent each. The exciters are directly coupled to the alternators.

Boilers.—Each of the four boilers is independently supported from the main structure and has two drums. Finned wall tubes of 3½in outside diameter are employed, and self-draining "Melesco" superheaters are fitted. Welded double-flow economisers are used.

The evaporative capacity of each boiler is 300,000 lb of steam per hour at 625 lb per square inch and 865 deg. Fah. Pulverised coal is supplied to each boiler by three "Lopulco" pulverising mills. Automatic control is obtained by means of pneumatic-hydraulic equipment, together with steam temperature control equipment which operates the tilting burners.

Two single-inlet fans supply forced draught to each boiler, while induced draught is obtained from two double-inlet fans. In either case differential inlet control is employed. There are three exhauster fans to each of the boilers, driven by variable-speed motors.

Dust is removed from the flue gases by electrostatic precipitators, from which it is extracted under vacuum and discharged into the sluicing system.

The ash is also removed by the sluicing system, which comprises two high-pressure pumps, two clinker crushers and two ash pumps, which deliver the ash to the settling ponds situated about 300 yards south of the boiler-house.

Coal-handling Plant.—The weekly coal consumption at a load factor of 20 per cent amounts to some 2000 tons. Supplies arrive entirely by rail and are unloaded by two 25-ton capacity combined tipplers and weighers arranged for side discharge. A single-belt conveyor transports the coal directly to the boiler-house; alternatively it is deposited on the coal store by a radial arm conveyor. This store has a capacity of 67,000 tons at 15ft depth. Stocking out and reclaiming are carried out by a drag scraper of 200 tons hourly capacity, which is also the capacity of the conveyors. In the boiler-house coal is distributed to the overhead bunkers by a travelling tipper.

Water Circulation.—The circulating water pump house is situated alongside Cavendish Dock and contains four horizontal double suction centrifugal pumps, each capable of pumping 23,000 gallons per minute against a 40ft head.

Steel pipes lined with bitumen and supported above ground at intervals on piled foundations conduct the water across Salthouse Pool and into the reinforced concrete culverts at the turbine house.

Chlorination.—A 1000 lb per twenty-four hours automatic chlorination plant injects chlorine into the condenser cooling water—salt water from the dock—according to a clock-controlled programme.

Feed Water.—Feed water is supplied from the town main and passed through a base exchange softener which comprises two units, each of 2000 gallons per hour capacity. These require regeneration after every 56,000 gallons, a process which takes about an hour.

In addition there is a chemical injection pump with connections to each boiler drum, and separate low-pressure injection plant for each turbo-alternator unit.

Water Storage.—Water for general purposes and softened water is stored in overhead tanks. Reserves of feed water are kept at ground level outside the main building. Softened water recovery tanks and clean drain tanks are also provided, from which the recovered water is returned to the softened water storage and reserve feed water tanks respectively.

Auxiliaries.—The turbine house crane has a span of 89ft and is able to lift 65 tons with the main hook and 12 tons with the auxiliary hook.

Fire-fighting hydrants throughout the station are supplied by an electrically-driven pump and a standby diesel set. Fire protection for the auxiliary transformers is provided by an automatic water jet installation, which also includes an alarm system.

Workshop.—Equipment available in the workshop includes a 7½-ton travelling crane, a milling machine and 3ft 6in radial drill, bench and pedestal drilling machines, circular saw, and shearing and shaping machines. In addition there is a smithy and equipment for oxy-acetylene and electric arc welding.

Transformers and Switchgear.—The generators feed into 11·8/132kV, 36MVA transformers, which are situated in the 132kV switch compound. These transformers have on-load tap-changing facilities.

The main 132kV switchgear is also located out of doors and has a rupturing capacity of 2500MVA.

Beside the four generator transformers, with their oil circuit breakers and isolators, the switch compound houses two 132/3·3kV station transformers and four feeder circuit breakers, together with busbar couplers and bus section switches. All circuits are connected to a double busbar system.

The 3·3kV supplies for auxiliaries are taken from four unit transformers, which are directly coupled to the generators, and from the two station transformers. The larger motors operate on 3·3kV, while smaller units are supplied from the 415V switchboard. Auxiliary switchgear is housed in annexes adjoining the boiler-house and turbine room, and consists of air circuit breakers for 3·3kV and fused switches for 415V.

Control and Relay Room.—The control room is located in the administrative block within easy reach of the turbine hall by means of the footbridge. In Fig. 3 can be seen the main mimic diagram switchboard, showing outgoing 132kV feeders, bus sections, bus couplers, generators, synchroscopes, and a general purpose intake panel. In front of these panels are four desk panels for generator control, which accommodate boiler and turbine house telephones.

Adjacent to the control room is the relay room, which houses the direction relays for generators, station transformers, feeders, busbars, and the main station interconnecting meters.

The consulting engineers were Merz and McLellan, in association with James Williamson and Partners for the civil engineering works, and

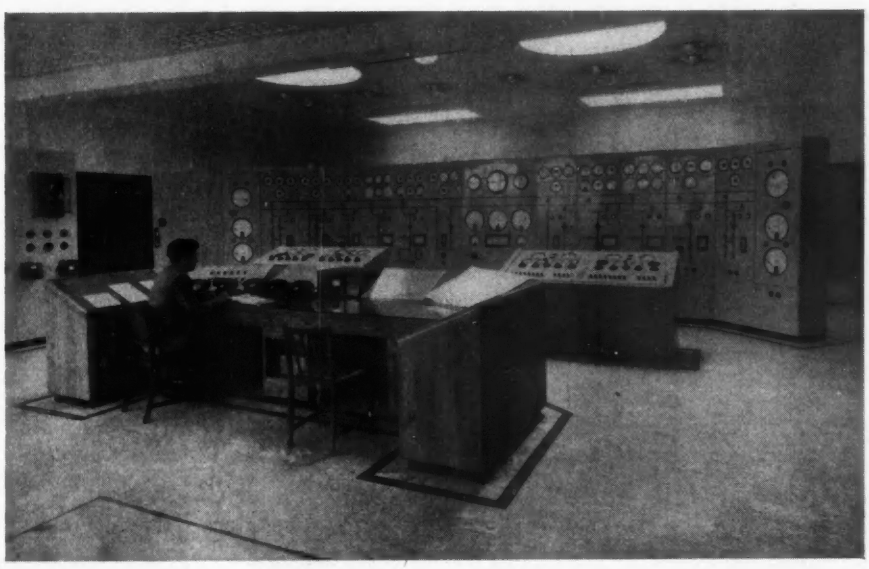


Fig. 3—Control room with main mimic diagram (in background) and four desk panels for generator control

L. J. Couves and Partners for the architectural and superstructure work.

PRINCIPAL CONTRACTORS

Civil Engineering Works.—Ground Explorations, Ltd. (site investigations), Barrow Corporation Water Department (water supplies), J. Gerrard and Sons, Ltd. (reclamation, main foundations and ancillary works, including circulating water culverts, coal-handling plant foundations, ash ponds and ash disposal plant foundations, 132kV substation foundations and superstructures, main superstructure), Bierrum and Partners, Ltd. (foundations for c.w. pumping station, inlet and outlet works at Cavendish Dock, erection of 60in c.w. pipes and footbridge), Horseley Bridge and Thomas Piggott, Ltd. (60in. c.w. pipes and steelwork of footbridge), B.C.S. (Engineers and Contractors), Ltd. (railway sidings).

Mechanical Plant.—Yarrow and Co., Ltd. (boilers), Robert Dempster and Sons, Ltd. (coal-handling plant), B.V.C. Industrial Constructions, Ltd. (ash and dust-handling plant), Metropolitan-Vickers Electrical Company, Ltd. (turbo-alternators), Vickers-Armstrongs, Ltd. (feed heating and condensing plant), Harland Engineering Company, Ltd. (boiler feed pumps), J. Blakeborough and Sons, Ltd. (circulating water valves), Aiton and Co., Ltd. (h.p. pipework, central evaporating plant), Simmons and Hawker, Ltd. (l.p. pipework), W. H. Allen, Sons and Co., Ltd. (c.w. pumps), William E. Farrer, Ltd. (c.w. screening plant), Clyde Crane and Engineering Company, Ltd. (65-ton crane), Permutit Company, Ltd. (water treatment plant), Wallace and Tiernan, Ltd. (chlorinating plant), Candy Filter Company, Ltd. (l.p. condensate treatment), Wharton Crane and Hoist Company, Ltd. (7½-ton workshop crane), J. Fowler and Co. (Leeds), Ltd. (diesel shunting locomotive).

Electrical Plant.—Ferguson Pailin, Ltd. (main switchgear), Metropolitan-Vickers Electrical Company, Ltd. (132kV and auxiliary transformers), English Electric Company, Ltd. (auxiliary switchgear), Drake and Gorham (Contractors), Ltd. (cabling), The North-Western Electricity Board (lighting administration building), James Scott and Co. (Electrical Engineers), Ltd. (light and heat, main building and site), Mather and Platt, Ltd. (fire fighting and alarm installation).

Building.—Dorman, Long and Co., Ltd. (steel-frame buildings), P. C. Richardson and Co. (Middlesbrough), Ltd. (brick chimneys).

Aluminium Centenary Exhibition

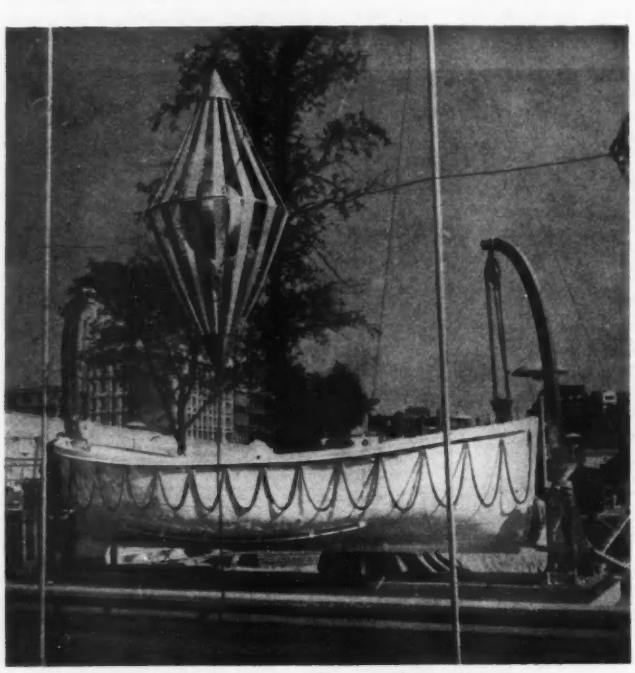
IN a note in our last week's issue we gave brief particulars of the exhibition which celebrates the centenary of the production of aluminium in this country. The exhibition, which closes to-day, illustrates in its various sections the technical development which has taken place, the present-day position of aluminium in the commercial field and in industry, and acts as a pointer towards future uses. The introductory display shows the bauxite from which aluminium ingot is produced by various processes, the cast slabs and billets, which are rolled into large plates or extruded into sections of various shapes, and gives an overall impression of the main stages in the production of aluminium semi-finished products. Exhibits in the historical section refer to the earliest production of aluminium in France and the first extraction in Britain, including photographs of the processes used at Wallsend-on-Tyne in 1889. The development of the industry is traced from 1894. Various commemorative medallions and examples of modern Italian and French coinage in aluminium are displayed.

A series of panels sets forth the chemical and physical properties of aluminium, such as its light weight, strength, permanence, good finish, high conductivity, non-toxicity, and easy working characteristics, and demonstrate the advantages offered in a number of applications in various industries. Models of modern aircraft using aluminium alloys are on view, and there is one of the "Silver Streak" the first British all-aluminium aircraft built in 1920. A forged and hot-rolled propeller blade made in 1925 for a "Hawker Heron" is shown and there are units machined from large extrusions and castings used for parts of engines. There are also examples of pressure vessels having a working pressure as high as 3300 lb per square inch and capable of withstanding 4950 lb per square inch on test, while fabrication is represented by a group of heat exchangers.

An extensive section of the exhibition is devoted to road transport and is broadly divided into passenger vehicles, commercial vehicles and motor-cars. Various engines largely built of aluminium illustrate the use of the material in power units, and the other exhibits demonstrate the production of diverse parts by various processes, such as casting, forging, die pressing, and other means of manipulation. Development in monocoque construction is typified in a double-decker bus, 27ft long by 8ft wide by 15ft 3in high, with seating capacity for sixty-four passengers and an unladen weight of 6 tons 14¼ cwt, which compares with the 7 tons 10 cwt of its fifty-six-seater predecessor. Another example of this form of construction on view is the thirty-five-seater B.O.A.C. coach, weighing 4 tons 18¼ cwt unladen. The use of aluminium for the bodies of commercial vehicles, to give a greater payload, can be seen in a National Coal Board tipper which has a body weighing 10¼ cwt and operates under severe and arduous conditions, including loading with coal in lumps weighing up to 4 cwt and which drop 14ft on to the floor of the body. Another example of the weight of the vehicle determining the payload is a bulk grain transporter and also on view is an all-aluminium commercial chassis unit designed to be integrated with the structure of a superimposed pantechnicon or platform lorry. A Rolls-Royce "Silver Ghost" motor-car of 1906 vintage serves to illustrate the extensive use of aluminium in motor-cars nearly fifty years ago, while a "Silver Wraith" saloon with all-aluminium coachwork illustrates present-day practice. Another outside exhibit is a London bus shelter representative of the hundreds which have been installed at bus stops during recent years.

Aluminium gives the designer full opportunity for following contemporary trends, and this is adequately shown by the variety of consumer goods displayed, including kitchen utensils, furniture, household accessories, office fittings, tableware, and sports equipment.

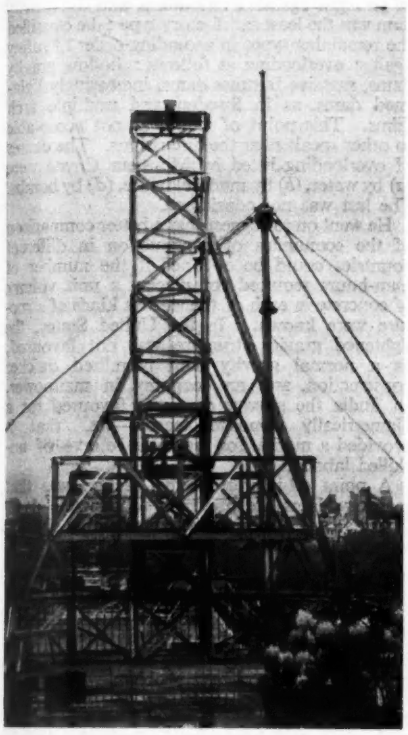
Light weight, combined with excellent resistance to corrosion of certain of the aluminium alloys, has led to the extensive use of the metal, for marine purposes ranging from a boat fitting to the superstructure of an Atlantic liner. The inside exhibits include a model of the "United States," in which some 2000 tons of aluminium was used for structural and other purposes, models of a cargo lighter and a ferry, and various ship and boat fittings such as a sidelight, a window, an anchor winch, stanchions, searchlight reflectors, and, one of the recent ship applications, oil tank heating coil pipes. Several ships' lifeboats are among the outside exhibits. Three modern boats demonstrate various forms of construction, including loose and built-in buoyancy tanks, and methods of using extrusions for gunwales and keels. One of the boats is carried in a set of argon-arc welded aluminium alloy davits, weighing 6 cwt



Aluminium alloy lifeboat carried in a pair of aluminium alloy davits

Hangar door leaf

each, which can be seen in our illustration. Brought out of retirement is the earliest lifeboat built of aluminium-magnesium alloy, the well-known "Barnacle Bill," which, although constructed in 1934, is still in excellent condition. Another boat of considerable interest is the self-righting airborne lifeboat which weighs 4460 lb and is slung under the aircraft fuselage and dropped by parachutes. Also on view is a 13ft speedboat which has a weight of 5½ cwt and a speed of 34 m.p.h., and is identical with the boat which the aluminium industry presented to the Duke of Edinburgh. Other exhibits which exemplify the advantages of aluminium alloy, in the marine field, are a ship-to-shore gangway having a length of 66ft and weighing 30 cwt, and designed to take a load of 19,500 lb without excessive deflection; hatch covers; diesel engine crankcase doors; an asdic dome



30ft high all-purpose servicing tower with transverse cantilever platform

body; a radar tower and a lattice mast for a fast patrol boat. During part of the exhibition the Admiralty made available an inshore minesweeper which has a length of 106ft by 21ft 3in beam, a displacement of 137 tons, and is of composite construction with wood shell planking over aluminium alloy frames forming the hull and the majority of fittings in light metal. Perhaps the most important marine exhibit is the motor yacht "Diana II," which has the following dimensions:—Length between perpendiculars, 55ft; breadth moulded, 12ft; depth moulded, 6ft 3in, and displacement, 10·5 tons. The vessel, except for the decking and furnishings, is built entirely of aluminium alloy and was launched as long ago as 1931. During the intervening years she has suffered various mishaps, was commandeered for war service, and is still in remarkably sound condition. All essential parts of the structure are free from any serious deterioration and after twenty-four years' of service the yacht remains as a visible proof of the suitability of the aluminium-magnesium alloys for marine purposes.

Numerous fittings and components form the inside exhibits of the railway section, such as brake gear, carriage fittings, a buffer working on an air-hydraulic system, and an example of a recent development, namely, a "slam" door for carriage stock. As early as 1905, aluminium sheet and aluminium alloy castings were used for coaching stock, while cars built in 1916 for the Manchester–Bury electric service are still in use. Modern application to railway stock is represented by one of the ninety cars now in service on the District Line of the London Transport Executive. In this unit the use of aluminium reduced the tare weight by 14 per cent and effected a saving of 12 per cent in power consumption. Another exhibit is a British Railways diesel railcar, which utilises aluminium buffers and in which the use of aluminium resulted in a saving of 4 tons and so permitted the installation of power units of moderate capacity. A full-size section of the subway cars built for the Toronto Transit Commission demonstrates the form of construction adopted and this can be compared with the design of the London Transport stock.

The packaging section illustrates the influence of aluminium on package design and on containers of various classes, all of which make use of the fact that the material can be seamed, brazed, welded, folded and shaped by spinning, pressing or drawing. Exhibits in the building section show the wide application of aluminium in this field and include examples of rainwater goods, windows, glazing bars, household fittings, ladders, scaffolding, a street lighting standard, and roofing work. Outside are exhibits demonstrating constructional systems, such as curtain walling, partitioning, roof decking and tiles, and prefabricated buildings.

The wide application of the aluminium alloys to structural engineering are well demonstrated by inside and outside exhibits. The former includes models of the double-leaf bascule bridge at Aberdeen; the hangar having a clear span of 200ft at Hatfield aerodrome; and a transportable hangar. There are also examples of riveted construction and various forms of rivet heads; a quadrant for slot aerial and a panel showing some British Standard sections, together with some of the bulbed and lipped sections developed to provide for the economic use of aluminium alloy in structures. The outside exhibits give some idea of structural items designed in aluminium alloy. There is a section of prefabricated stressed skin roof, weighing 1·8 lb per square foot and capable of taking an applied load of 20 lb per square foot, also a leaf of a large hangar door measuring 50ft in height by 25ft wide, which is shown in our illustration. Another item is an all-purpose aircraft servicing tower, which we illustrate; it has a height of 30ft and a transverse cantilever platform formed from standard elements which permit the construction of a variety of tower and staging structures. An impressive exhibit is the 170ft jib, for a walking dragline machine, which is framed in extruded sections and plate using hot driven mild rivets as a jointing medium. The length of the jib has been achieved by reason of the use of fully heated strong aluminium alloy, and the jib, which has a minimum working angle of 25 deg. with a bucket of 5 cubic yards capacity, weighs about 11 tons.

In the next section is demonstrated the use of aluminium in chemical engineering, where the high resistance of the metal to attack by a large number of chemicals is of advantage. Aluminium of not less than 99·5 per cent purity is mainly used, although where greater strength is required certain alloys are employed. The exhibits indicate the versatility of the metal and include tower packing rings, pipework fabricated by argon-arc welding, bursting discs used as safety valves in chemical processes, a high-pressure contra-flow heat exchanger and castings for a filter press. Several items are representative of the wide acceptance of aluminium in general engineering and include the Ricardo steam engine, various items of handling equipment, such as a truck, a pallet and an elevator bucket, parts of machine tools, textile machinery parts, and printing equipment, &c.

Because of its high electrical conductivity aluminium has long been employed in electrical engineering, being used for overhead conductors as long ago as 1898, and many items in the electrical section are of early applications. There is an exhibit of the largest steel-cored aluminium overhead conductor, weighing 4·77 lb per foot, which is of 37/108 construction and 2·295in diameter, and was made for the Kemano-Kitimat project in British Columbia. Low-tension distribution conductors are represented, also insulated power cables and many examples of busbars and switchgear, while items used in telecommunications can be seen, including a specimen joint in the experimental fifty-four pair 10-mile cable with aluminium conductors and polythene sheath. Another part of the electrical section is devoted to windings, and among the exhibits is a small transformer, in which the weight has been reduced by 50 per cent by using anodically insulated aluminium wire windings operating at 140 deg. Cent. Among the outside exhibits there is a 420kVA experimental transformer with aluminium windings and argon-arc welded joints.

Another section of the exhibition is concerned with agriculture and food and the exhibits show the application of aluminium to farm buildings, such as poultry houses and grain silos, and to a variety of farm implements. Horticultural applications are represented, while other exhibits demonstrate the use of the metal for various purposes in the dairy and bakery and in the fishing industry.

A photographic display shows research work in progress on different aspects of aluminium technology, and among the products shown, resulting from recent research, are sintered aluminium, aluminium-tin bearings, hot-dip aluminised steel, and integrally stiffened sheet made by a special rolling process, which pressure welds ribs on to aluminium alloy sheet in one continuous operation without loss of flatness.

Diesel-Electric Locomotives for Rhodesia

TWENTY-THREE 2000 h.p. diesel-electric locomotives are being built by the English Electric Company, Ltd., for service on the 170-route-mile 3ft 6in gauge section of Rhodesia Railways between Salisbury and Umtali. These locomotives have a $1C_0–C_01$ wheel arrangement and with a total weight of 113 tons are designed for a maximum axleload of 15 tons. They have a starting tractive effort of 60,300 lb and a continuous tractive effort of 36,000 lb at 13·4 miles an hour.

Each locomotive is carried on two cast steel bogies guided at the outer end by a Bissel truck. The riding qualities are improved by each bogie having two separately equalised wheel sets—the Bissel truck axle and the adjacent motored axle, and the remaining two motored axles. The power unit comprises a sixteen-cylinder, four-stroke, pressure-charged, diesel engine rated at 2000 h.p. at 850 r.p.m., under standard conditions of temperature and pressure. This engine is coupled to the main generator which is bolted rigidly to the bed-plate and crank case. The auxiliary generator is overhung on the free end of the main generator and supplies current for the auxiliary machines and battery charging. The main generator supplies current to six traction motors which are connected in three parallel groups, each group comprising two motors in series.

The locomotive output is controlled by varying the speed of the diesel engine and the field strength of the main generator. The method of control is such that the load imposed on the engine is automatically adjusted to coincide with the available engine horsepower, irrespective of the engine or locomotive speed.

Book of Reference

Water Engineer's Handbook, 1955. London: The Colliery Guardian Co., Ltd., 30/31, Furnival Street, E.C.4. Price 18s.—The 1955 edition of this reference book is arranged in the customary manner, with a directory of water undertakings in the British Isles, waterworks statistics, and other information relating to water engineering, such as lists of river boards and governmental and other bodies. The technical section covers the same ground as in previous editions, but the volume has three new sections as follows: new works under construction and projected (this section comprises an alphabetical list of undertakings and a brief statement of the new works they are engaged on); river purification boards in Scotland with officers and addresses; and civil defence (water supply) regulations 1949—mutual aid groups in England and Wales.

Fifth Congress on Large Dams

No. I

The fifth international congress on large dams, organised by the International Commission on Large Dams of the World Power Conference, was held in Paris last week. A brief résumé of the subjects discussed at the congress is given in this article.

WATER conservation, whether for the generation of hydro-electric power, for irrigation, or for other uses, has been developed at a rapid rate in many countries since the war ended. These activities show every evidence of continuing or even increasing in magnitude in the near future, so that technical progress in the construction of large dams, on which they ultimately depend, has also been rapid. The international congresses organised by the International Commission on Large Dams, and held every four years, provide a useful record of progress in this field, and are in themselves a stimulant to further progress. That the art of constructing large dams has reached an advanced stage of development is evident from a perusal of the subjects—the "questions" as they are called—discussed at the fifth congress which was held in Paris last week. That work is proceeding on a large scale in many countries, and hence interest is widespread, is also evident from the fact that about 140 written contributions were made to the congress.

Discussion on the written contributions proceeded throughout last week, at the Maison de la Chimie. The congress also included a number of social events and tours of constructional works in France and North Africa. Some of the delegates toured the French schemes the week before the congress itself took place, and the North African tours followed the congress, and are still in progress. With all this activity, obviously only a brief résumé of the work of the congress can be given here; our description is divided, first, into notes on each of the four main questions. Then we have attempted to mention from the contributions of each country one or two developments which seem of particular note. Generally the titles of the papers and communications are not given, but the references in brackets refer to the number of the paper in the congress classification.

The main work of the congress sessions concerned discussion of the four questions, namely:

Question 16: Design and construction of dams on permeable soils and methods of foundation treatment.

Question 17: Economics and safety of different types of concrete dams.

Question 18: Settlement of dams due to compressibility of the material of the dam or the foundation soil, including earthquake problems.

Question 19: The relation of the cement content of the concrete to performance in practice of (*a*) gravity dams; (*b*) arch dams; (*c*) buttress dams; and its influence on permeability and frost resistance.

There were general reports on each group of papers in these categories. Also thirty-six "communications" not grouped in this classification were presented. One of the papers in question 19 (R70) was a report submitted by the International Sub-Committee on Concrete for Large Dams on frost resistance and on the definition of concrete mixes.

The "questions" themselves are chosen so that the discussion centres round problems of wide interest where more knowledge is needed. Their titles, therefore, give an indication of contemporary problems. At the fourth congress, held in New Delhi in 1951, the "questions" were: question 12, flood discharge and spillway design; question 13, earth and rock fill dams; question 14, silting of reservoirs, and question 15, concrete for large dams.

Dams on Permeable Soils

The thirty papers comprising question 16 are concerned with the following topics: preliminary foundation studies, both theoretical and experimental; water-tightness of foundations, and methods of controlling permeability in different foundation soils; and consolidation of foundations by grouting or drainage.

Numerous examples are given of recent works in a number of countries where construction of a dam has been preceded by extensive foundation surveys, aimed either at securing adequate impermeability in the completed structure, or at overcoming the particular constructional problems of the site. For instance, R. C. Rao (R.49) describes the foundation problems at Tungabhadra and Hirakud dams. A typical case of a new project needing extensive surveys is that of the Serre Ponçon dam in the French Alps. The site has been investigated by varied methods, including a drilling programme involving 10,000m of drilling, permeability measurements, pumping tests, core-drilling, and the injection of colouring substances and radio-active isotopes. The site is a glacial valley partly filled by stratified alluvial deposits, which extend to a depth of 100m, and are heterogeneous in character. This work is described by Ischy and Haffen (R.80).

The Serre Ponçon dam will be an earthen embankment 120m in height. Following the investigations just described, it was decided to construct an impermeable screen, 110m in depth, below the dam by grouting with slag cement ground in water and bentonite clay. This work is described by R. Maigre (R.79); he points out that although this solution is simple in principle, the actual techniques of grouting need to be based on large-scale tests and the work done with care, if economy is to be achieved.

A general review of grouting problems is given by Grundy (R.66), who also emphasises the practical skill and site supervision needed for such work. European and American practices are discussed in his paper, as are various special methods used in alluvial soils. Mr. Grundy points out that the absence of any standard form of recording the results of grouting work often makes comparisons difficult.

An interesting example of the consolidation of a clay foundation is described by Cambefort and Daxelhofer (R.42). The Ben Metir dam, a gravity structure 60m in height, is built on a clay foundation which has been drained by an extensive system of drains leading to four principal tunnels 20m below the dam. A larger protective water-tight screen was constructed than would have been necessary without the drains. Two examples are given in other papers (R.59 and R.57) of earth embankments built in Britain, which incorporate sand drains, in a clay soil.

The performance of foundations is also considered in some of the papers. Walker (R.1) points out that little has been written on the appraisal of seepage from structures in operation. More attention needs to be given, the author considers, to the development of sound maintenance practice; it is essential, he postulates, to have performance records for all structures built with foundations that are not impervious, and it is dangerous practice to discontinue such studies at the first indication of good performance.

The general reporter for question 16 was J. F. Rebelo Pinto, of Portugal.

Gravity, Buttress and Arched Dams

The economy and safety of different types of concrete dams was the subject for discussion in question 17. Eighteen papers were presented, and the general reporter was A. Coyne. Some controversy was evident in the discussions; it was pointed out, and was generally maintained by all the authorities at the congress, that each particular site must be considered as an individual problem, and no preference for a certain type of dam could be generally valid. Nevertheless, the designers of different countries seemed to have different ideas which to some extent overruled the general principle. These differences were brought out in Monsieur Coyne's general report. He noted, for instance, that a simple rule for deciding whether a valley was suitable for an arch dam had been proposed by Hammond (U.S.A.), namely, that the "shape factor" (i.e. ratio of the perimeter of the base of the dam to its height) should not exceed 4·5. However, a small arch dam in France had been built where this ratio was 10·9, and there were four examples in France of arch dams where the ratio exceeded 5. In Italy, successful tests had been carried out on a model of an arch dam where the ratio crest length/height was 7, and this was considered to be about the limit. Monsieur Coyne considered that, *a priori*, the arch dam had the greatest stability and reserve of strength against overloading, and the gravity dam was the least satisfactory type; he classified the remaining types in ascending order of safety against overloading as follows: hollow gravity dams, massive buttress dams, increasingly lightened dams, as in Sweden, and multiple arch dams. This point of view was not acceptable to other speakers at the discussions. The causes of overloading listed by Monsieur Coyne were (*a*) by water, (*b*) by mud, (*c*) by ice, (*d*) by bombs. The last was not considered.

He went on to suggest that a better comparison of the economics of construction in different countries could be obtained if the number of man-hours required for placing a unit volume of concrete in each of the various kinds of structure were known. In the United States, the lightened gravity structure was not favoured, as a normal gravity dam permitted quicker construction, and an economy in manpower. In India the gravity dam was favoured for a diametrically opposite reason—viz. that it provided a market for the large reserve of unskilled labour.

A point of interest in this section was that masonry dams are preferred to concrete dams in India, and appear to be considerably cheaper to build (R.73).

Foundation Settlements and Earthquakes

In discussing question 18—the settlement of dams, due to the material of the dam itself or of its foundations, and the effects of earthquakes—a common problem with that of question 16 was evident. In both cases it was remarked that the best sites for dams—with rigid and impermeable bedrock—had in many cases been utilised, and construction in the future would have to contend with more indifferent geomorphological conditions. Hence the importance of these difficult problems of impermeability and settlement.

Twenty-seven papers were presented, and the general report for question 18 was by D. Tonini. Accounts of settlement problems in earth and rock fill dams constitute an appreciable part of this section of the congress. However, some special problems of loading and deflection of concrete dams—such as Maraetai dam in New Zealand (R.18) and Valle-di-Cadore dam in Italy (R.65) are also described. The special problems of constructing dams in an active volcanic country are noted by Hunter and Keefe (R.69). During the discussion one of the speakers pointed out that a project in Turkey envisages the construction of major structures in an active earthquakes zone, where the river valleys in some cases follow the faults where earthquakes are particularly felt; the frequency of major shocks is about 50 years. Is it possible, it was asked, to build reasonably safely and economically under these conditions? Although a number of dams have successfully withstood earth tremors, quantitative data on which to base a design does not seem to be readily available.

The karst formation of Yugoslavia—limestone districts where there are extensive underground streams—have given rise to difficult problems for the hydro-electric engineer. An account of the measures taken in building dams under these conditions is given in two papers in question 18 presented by Yugoslavian authors. The same problems have also been

encountered in other countries, but not to the same extent.

Concrete for Large Dams

Two groups of papers were presented in this section (question 19), namely, reviews of practice and of the behaviour of actual dams, and laboratory studies of permeability and frost resistance. There were twenty reports altogether, the general reporter being F. M. Lea.

Another general trend which became particularly evident in this section of the discussions was the need for a standard international system for comparing results. This question arose in the concrete sub-committee's report (R.70), in which recommendations are made on the definition of concrete mixes and on the minimum data which should be given in a brief description, and in a full report, of the concrete in a dam. These recommendations are to be publicised by the committee, and the report R.70 sold separately, for the benefit of concrete specialists generally.

Problems of concrete technology at present under investigation vary in different countries according to local conditions and needs, and cannot be summarised effectively. As an indication of one of the points on which discussion was invited we abstract the following paragraph from the general report. It concerns the cement content of concrete for dams, a discussion of particular interest to the United States engineers, who have reduced the cement content of some recent dams to a low figure.

It is of interest to note the considerable variation in the cement contents quoted for particular dams or in the reviews of practice in the reports from different countries. For the facing mixes of massive gravity dams the contents in modern dams vary between 376 lb per cubic yard (223 kg per cubic metre), combined with the use of air entrainment, and 620 lb per cubic yard (367 kg per cubic metre) in thin facings without air entrainment. For the hearting mixes of massive gravity dams the contents vary from 230 lb per cubic yard (136 kg per cubic metre), or even 188 lb per cubic yard (111 kg per cubic metre) with air entrainment, up to 376 lb per cubic yard (223 kg per cubic metre) without air entrainment. It is even more difficult to distinguish world trends in the cement contents of arch or buttress dams, although there is a natural tendency in any one country for them to be rather greater than in massive gravity dams in the same country. In the case of arch dams the figures quoted vary from an overall average of 548 lb per cubic yard (325 kg per cubic metre) in one country down to 278 lb per cubic yard (165 kg per cubic metre) for a particular dam in another.

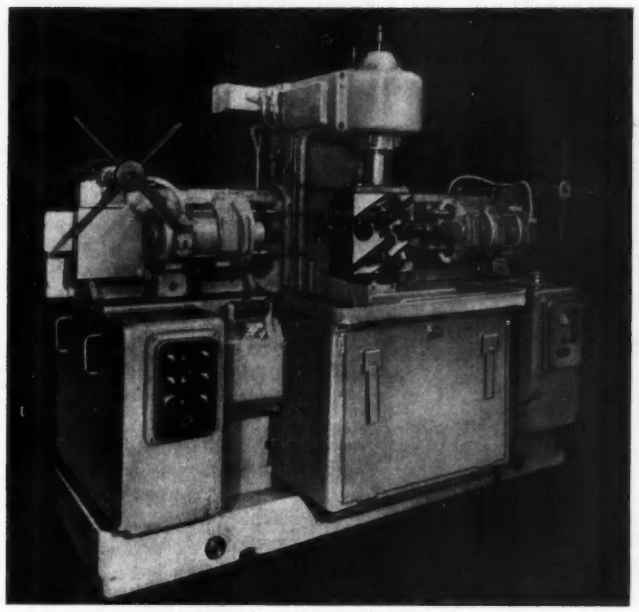
(To be continued)

Short Notice

Ueber Die Temperatur Verteilung Hinter Angestroemten Zylindern. By J. Ackeret. *Ueber Thermische Effekte in Resonanzrohren.* By H. Sprenger. *Schubvermehrung Durch Strahlmischung.* By Zbigniew Plaskowski. Zürich: Verlag Leemann, Arbenzstrasse 20. Price 13.50 francs.—These three papers are published together as No. 21 of the series of research reports issued by the Aerodynamics Institute of E.T.H., Zürich. In his paper, Professor Ackeret deals with the temperature distribution in the wake of cylinders, particularly with the cooling effects observed by L. Ryan (Report No. 18 of this series). In his experimental investigations Dipl.-Ing. Sprenger shows that large temperature increases can occur in close-ended pipes under conditions of resonance. The vibrations are excited in the same way as in the Hartmann ultrasonic resonator, by a gas jet directed at the open end. If a small opening is made near the closed end, the escaping gas has a temperature below the throttling temperature, so that the resonator tube can be used in the same way as a Ranque vortex tube to separate the expanding gases into hot and cooled partial jets. The third paper gives the theory of aerodynamic thrust augmenters which may be of assistance in take-offs. Measurements carried out by the author show the difficulties which would have to be faced in practice, due to the great length of the mixing duct required.

Horizontal Drilling Machine with Indexing Fixture

A deep hole horizontal drilling machine with two opposed heads and fitted with a hydraulically-operated, two-station, indexing fixture has been built by Adcock and Shipley, Ltd., Leicester, for drilling the oil holes in four-throw crankshafts. As can be seen from the illustration on this page the central indexing fixture has a horizontal, two-spindle, drill head on each side and the heads are designed to drill a pair of holes in the components simultaneously from both sides. The machine was built to the requirements of Humber, Ltd.



Horizontal drilling machine with two opposed multi-spindle heads and central hydraulically-operated clamping and indexing fixture

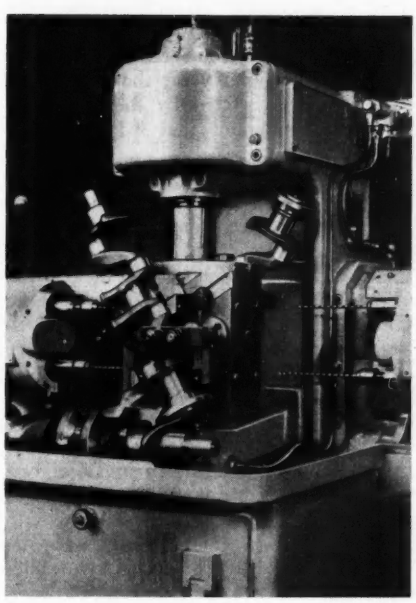
In the cycle of operations, a crankshaft is loaded on to the front of the fixture with its No. 1 throw uppermost, and after indexing the holes are drilled from the main bearings to the No. 3 and No. 4 big end bearings. While this operation is in progress the shaft previously drilled is taken out of the fixture reversed, and reloaded with the No. 4 throw uppermost for the subsequent drilling of the No. 1 and No. 2 big end bearing holes. On each fourth indexing, therefore, a completely drilled crankshaft is removed and replaced by a new shaft.

When a crankshaft has been loaded on to the fixture, the cycle is started by depression of the two levers to be seen on the cabinet below the left-hand drill head. Immediately the fixture begins to rotate hydraulic pressure is applied to the clamp to hold the shaft rigidly. When the operator releases the levers at the conclusion of the indexing movement, a locating plunger engages and holes the fixture for the automatic drilling cycle which is started by depression of a switch button. In the drilling cycle, the two heads approach the work at the rate of 300in a minute and change to the feed rate of 0·0019in per revolution immediately before drilling commences. During the drilling cycle, the heads make one rapid withdrawal, swarf clearing movement, and just before the hole is finally broken through, one of the heads is automatically retracted while the other completes the hole.

The two horizontally opposed drill heads are mounted on slides over the cabinet base of the machine and each is driven individually by a 2 h.p. 1430 r.p.m. motor. The drills used in this case are $^{7}/_{32}$in diameter, and are fitted to standard collets with individual setting adjustments of 1in. Through capstan wheels the heads can be adjusted over a distance of 1¾in by hand. Pick-off gears are supplied for speed and feed rate adjustment and provision is made for feeding, indexing and clamping by hand for testing and setting-up. The hydraulic feed is actuated through a servo mechanism operated from cams rotated by a separate feed motor driving through pick-off gears, which can be changed to alter the cycle timing.

The machine consists of a base designed to form a coolant tank, and upon which is mounted a box containing the hydraulic control mechanism. On the extreme right and left-hand sides of the base are two cabinets. The left-hand cabinet has a switch panel on its front, and contains the electrical control gear; the right-hand cabinet contains the hydraulic power unit. A large capacity centrifugal pump in the base feeds coolant to the guide bushes in the fixture, a strong jet of fluid being directed down the holes to clear swarf and cool the drills.

Special attention has been given to the problem of swarf accumulation and the front of the machine is equipped with a large sheet metal cabinet enabling the coolant and swarf to be collected in a special sheet metal swarf barrow housed inside this cabinet. The bottom of the swarf barrow is fitted with grids to enable coolant to drain out. The front of the cabinet is hinged at the bottom to allow the swarf barrow to be pulled out in its wheels, for removal by fork-lift truck and replacement by an empty barrow.



Hydraulically-operated indexing fixture with undrilled crank at front station and drill heads approaching crank at the rear station

Coal Board Stores Department.—In accordance with a recommendation of the advisory committee on the National Coal Board's organisation, a purchasing and stores department is being set up. This department has been established at the Board's national headquarters, and at divisions and areas and will operate from July 1st. A director-general for the department will be appointed and there will be divisional purchasing and stores controllers and area purchasing and stores managers. Mr. R. H. E. Thomas is the member of the National Coal Board responsible for the department.

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THE STRIKE AND ITS AFTERMATH

One of the consequences of the strike of members of the Associated Society of Locomotive Engineers and Firemen has been to show how much and how little the people of this country are dependent upon the proper operation of its railways. It is already obvious that should the present situation persist for any length of time many industries must inevitably be seriously affected either by shortage of raw materials—the iron and steel industry is already feeling the effects—or by the difficulty of removing quickly enough the products of their activities, as, for example, coal from pitheads. Yet despite the virtual disappearance of main line trains and suburban traffic people are still managing—mainly by road—to carry on with their vocations, albeit at great inconvenience. Indeed in London and other large cities valuable lessons are unexpectedly being learnt. Despite the increased number of vehicles operating, traffic is still being kept moving. Only the future will permit the effects of the strike to be completely assessed. But there can be little doubt that when the matter is eventually settled British Railways will turn out to be a loser. Not only has traffic been lost to the roads ; but in addition, traffic that might have been attracted back to the rails by consequence of the railways' new freedom to quote special rates, may now continue to go by road. Those consequences will follow from the refusal of A.S.L.E.F., adamant up to the time of writing, to consider any proposals other than those it has itself put forward for increasing the differentials in the rates of pay of its members relative to other grades; and its equally adamant refusal to enter into three-cornered negotiation between itself, the British Transport Commission and the National Union of Railwaymen.

Engineers, we think, can hardly help feeling a certain sympathy for the drivers and firemen now on strike. Repeatedly since the war, within the engineering industry, it has been pointed out how much damage is being done by the fall in the differential rates of pay as between skilled and unskilled men. There is far less incentive now, it is maintained, than there was between the wars for a lad to enter upon a term of apprenticeship and to acquire a skill. For, at best, after several years' training he will be able to earn an income no more than a few shillings a week greater than that of his unskilled companions ; and, at worst, he may find them, at work in a mass-production factory, commanding higher wages than he can earn by his skill. Thus it must seem to engineers reasonable that the more highly skilled railway workers should have their reward in adequate differentials. Furthermore, sympathy for those on strike must also be generated by the history of the wage negotiations that led up to the strike.

The present dispute dates back to October last. Early in that month, after nine months of negotiation, agreement was reached on a revised wages structure for the railways, excluding the footplatemen. In those negotiations the three railway unions—the National Union of Railwaymen, the Transport Salaried Staffs Association and the Associated Society of Locomotive Engineers and Firemen—participated. By the terms of that agreement, railway wages were increased by, in most cases, rather more than the 15 per cent claimed in December, 1953. As an example, the weekly basic wages of a top-rate signalman were increased to £8 17s., and of a guard, with four years service, to £7 11s. The locomotive men's new rates were not then determined, however, as the executive of A.S.L.E.F. insisted that they should be examined by the Railway Staff National Tribunal, which is the final stage in the joint negotiating machinery. The Tribunal's award was that maximum weekly basic rates for drivers and firemen, to be reached in the third year of service, should be £9 12s. 6d. and £7 18s. 6d. respectively and for engine cleaners £6 9s. Meanwhile the N.U.R. had repudiated its acceptance of the October settlement, and, following the report of the Court of Inquiry set up in December last, further increases were given to date from January 10th. These increases brought the basic weekly wages of a top-rate signalman to £9 10s. and of a guard, with three years' service, to £8. For the locomotive staff the British Transport Commission proposed that the maximum basic weekly rates should be £9 15s. for drivers and £8 4s. for firemen, in the third year of service, and £6 15s. for engine cleaners in their second year of service. Those proposals were acceptable to the National Union of Railwaymen, to which about 25 per cent of British Railways locomotive staff belong, but were rejected by the executive of A.S.L.E.F. The latter union submitted a claim to the Railway Staff National Tribunal, which sought maximum weekly rates of £10 0s. 6d. for " third-year " drivers, £8 6s. 6d. for " third-year " firemen and £6 17s. for " second-year " engine cleaners, in order to maintain at least some part of the differentials gained in consequence of the October agreement with the N.U.R. and the following Tribunal award to A.S.L.E.F. After considering this claim, the Tribunal announced its decision on April 14th, the finding being in support of the British Transport Commission's offer and rejecting A.S.L.E.F.'s subsequent claim. It will be seen that, in general, the wage increases for the locomotive grades offered by the Commission, and endorsed by the Tribunal, were in excess of the 15 per cent demand which A.S.L.E.F., in company with the other railway unions, made towards the end of 1953. But it will also be seen that the differentials that the Tribunal awarded A.S.L.E.F. members after the October settlement with the N.U.R. were not maintained by the Tribunal's April decision—a peculiarly irritating reversal of policy. The situation was made all the worse in that, obviously, A.S.L.E.F. wanted its latest claim to be met in full ; yet if it were conceded, then the executive of the N.U.R. had made it very plain to the Commission that it would press for further increases for those railway grades which it represents. The Transport Commission subsequently made further proposals, which included the division of the locomotive men into two grades to take account of their varying degrees of responsibility. The proposals also included an improvement in the mileage bonus. But the executive of A.S.L.E.F. was adamant in its refusal of these proposals and declared that the strike, which had been postponed from May 1st, would begin at midnight on Whit Saturday, May 28th ; and so it did.

Those are of course only the bare bones of a dismal history. Other factors, too, are involved. One of them undoubtedly is that labour relations on the railways have not been good since the war. The cause can probably be traced back to nationalisation. Experience of grouping after the first world war showed that men cannot

lightly transfer loyalty from a smaller to a larger concern ; it takes a generation or more to develop. Again when there is an amalgamation, the new central body, in order to make its authority effective must for a while concentrate all but minor decisions within its own hands. Executives are thus rendered less able than before to make their own decisions and so by prompt action to prevent grievances from smouldering into such an action as a strike. The British Transport Commission is not alone in feeling such effects ; they have been very apparent since the war in the coal industry and elsewhere. Had workers had a better feeling of loyalty and a higher pride in the industry they serve, they would have proved less willing to strike. Furthermore it is probably not at all well appreciated amongst the men affected that there is nothing sacrosanct about differentials. As Lord Beveridge has pointed out in a letter to *The Times*, they have varied substantially through the centuries, fluctuating in dependence upon the economic conditions of the times. Under conditions of general labour shortage such as now rule in this country, it may well be that economic forces tend to keep differentials low, however irritating that fact may be to skilled men and however much it may tend to embitter relations between craft unions and general ones. Nor should the point be wholly neglected in so dynamic an age as ours that the relative content of skill in different trades may be altered by technical developments. The driver of an electric or diesel locomotive carries as much responsibility as the driver of a steam locomotive. But does he have to exhibit as much skill ? To what extent are track-circuiting, automatic train control, interlocking of signals and points and so on affecting the relative degrees of skill exhibited by drivers, firemen, signalmen and guards ? The effects of these and other factors have all, no doubt, contributed to the creation of a climate in which patience failed and a strike became inevitable.

But though it is possible to feel sympathy with the members of A.S.L.E.F., it is quite impossible to feel that anything in the situation justified strike action. Only a failure of patience—perhaps as much on the side of the Commission as on that of the union—led to the strike. For in these days, and especially in a nationalised industry, strikes serve no purpose. Nationalised industries—able at need to call upon every Governmental resource in their support—are far too powerful to be dragooned into surrender by strike action. Eventually a settlement must be reached by negotiation ; and if so, what value is there in strike action ? The essential thing now is to bring to an end a strike that was ill-conceived from the first ; and the uttering of belligerent statements about not negotiating under duress or of refusal to sit around the same table with another union are evidences neither of good sense nor of firmness, but merely of an irritated temper. It would, too, have been wiser, in our view, if the Government, instead of making conditions, had merely continued its endeavours to bring the parties to the dispute to some understanding. The T.U.C., by unremittingly seeking a means of reopening negotiation has played the better part. By the time this issue reaches readers it may have proved successful.

But the ending of the strike—we hope an end may be at least in sight by the time these words are read—does not finish the affair. Two labour issues have been raised by it. Unquestionably there entered into the calling of the strike an issue of inter-union jealousy. That jealousy is also the prime issue in that other strike, almost forgotten during this last two weeks, but still dragging on, which is very seriously hampering the loading and unloading of ships. The whole trade union movement—as the T.U.C. well recognises—must be brought into disrepute if quarrels between unions are permitted to inflict upon the people of this country the very serious damage that the dock strike and the railway strike have inflicted. The other issue is that of determining how, without wholly depriving men of the right to strike, to prevent a single union like A.S.L.E.F., too much pre-occupied with its own ends and losing patience in negotiation, from threatening disastrous consequences for the whole of this country's economy. For there can be no doubt about it. If the strike is continued the consequences will be disastrous. Nothing can fully take the place of rail transport. Industrial production, so far maintained very largely by the Briton's genius for improvisation in emergency, must soon fall. A continuance of the strike must necessarily force the nation back into that weak economic state from which heightened industrial production has only but lately rescued it. How are these two problems to be solved ? How is inter-union jealousy to be controlled ? And how are strikes in major industries to be prevented ? Those are no doubt questions that stand primarily to be resolved by the T.U.C. But, as we remarked last week, we regard it as fortunate that the election returned to power a Government not committed for the next five years to undertake a controversial programme of legislation, and one therefore which may have the time, and we hope, also the qualities of good sense and good temper necessary for the study of those problems.

Literature

Servomechanism Practice. By WILLIAM R. AHRENDT. London : McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 50s.

THE author of this excellent book is fortunate in being the head of a well-known American company concerned with the manufacture of small servomechanism equipment, and at the same time a University lecturer on the subject. This gives him an unusual combination of experience in dealing with the practical aspects of servomechanism design and the problems of teaching its theory to students. In recent years a great number of books have been published on this general subject, most of them in the U.S.A., but very few have dealt with the practical problems which are encountered in the engineering of the devices. This book, therefore, fills a definite gap in existing literature and in spite of its comparatively high price will be of outstanding interest to many engineers and students. The book is concerned mainly with the lighter type of servomechanism, making use of electronics and electro-mechanical units, although there is some reference to hydraulic problems. If the purist might object to the opening paragraph defining a servomechanism, a quick glance through the book will soon indicate the scope that it covers. Process control systems, regulators and the like are not discussed nor are such heavy installations as ship steering or machine tool gear.

Initial chapters deal with the operation of a simple electronic servomechanism, the design and use of potentiometers, synchro devices of various types, modulator or vibrator devices to convert a.c. to d.c. signals and vice versa, the treatment being as thorough as could be wished in a book of this type. Then follow chapters on various types of network for filtering or phase shifting, and an interesting chapter on the design of servo amplifiers where the differences between these amplifiers and those used for sound reproduction are outlined. As the author says, a power amplifying device which can be fed from a servo amplifier can withstand an immensely higher level of distortion than can the human ear and therefore the problems are different. He devotes a considerable portion of this chapter to the subject of thyratrons making the point that existing literature on thyratron servo amplifiers is very deficient.

Following chapters deal with rate or tacho-generators and small servo-motors of the type used on the output end of many small servo systems. There is a good chapter on magnetic amplifiers ; many engineers who shudder at the thought of designing ordinary mechanical machines to contain electronic valves will find encouragement in a chapter showing how many of the circuits used at present with valves can be replaced by circuits using magnetic amplifiers, which are very robust and like transformers can operate for years with no maintenance. The fascinating prospect of the combination of transistors with magnetic amplifiers is deliberately avoided, presumably because the existing knowledge of transistors is much too sparse, at present, to write a book about. Chapters on rotating amplifiers of the Ward-Leonard type, and on hydraulic systems and components will be found to be of general interest. In the latter chapter the description of a small jet control hydraulic valve is of particular interest (on page 202 there is a misprint, an orifice of 0·008in being printed as 0·0008in). Two long chapters on the design and manufacture of servomechanisms contain a great deal of interesting material which the author's experience makes authoritative. Several pages of information on gear design and manufacture should be studied by many electronic engineers who design servomechanisms. Concluding chapters deal with the adjustment and servicing of servomechanisms and their testing. An appendix to the book contains a very well done summary of the theory of servomechanisms.

The book is well printed and the diagrams are admirably clear. The author and its publishers are to be congratulated on it and it can be whole-heartedly recommended to all engineers concerned with the design of electrical, mechanical or hydraulic servo systems.

Engineering Cybernetics. By H. S. TSIEN. London : McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 46s. 6d.

OF recent years, the word "cybernetics" (coined from the Greek word meaning "steersman") has loomed rather ominously on the horizon of the control engineers'

view and has tended to be numbered among those things about which he must become better informed. First of all, then, let it be stated that cybernetics, in the classical interpretation according to Weiner, is the science of control and communication in both animal and machine, and in his book on the subject, a general survey, partly philosophical, partly pathological and partly analytical was given. This book, however, merely identifies the subject and it is left to H. S. Tsien in the present book under review to gather together the tools, many of them well developed, which now become part of the newly defined subject of engineering cybernetics.

The book begins with a sketchy outline of the Laplace transform of insufficient detail to indicate a method of solution. Transfer functions are then discussed and an account given of the methods of Bode and Nyquist for the determination of the stability characteristics of a control system. The feedback servomechanism is discussed in its application to linear systems with constant coefficients and the non-interactive system, such as a turbo-jet engine, touched upon. An interesting chapter is devoted to alternating current and oscillating control servomechanisms and the concepts of Bode and Nyquist modified to suit their analysis. Special types of systems, such as the sampling servomechanism and the relay servomechanism are discussed and a good introduction given to the methods available for the analysis of such systems. A chapter is devoted to the linear system with time lag and effort is concentrated on a modification of the Nyquist approach at the expense of considering a formal solution. Linear systems with random inputs are also touched upon and, at a later stage in the book, the specific problem of the filtration of noise discussed. Design of control systems involving non-linearities are considered as also is the problem of the analysis of linear systems with time variable coefficients, but any such discussion is bound to suffer from the limitation that analysis of non-linear systems, in the present state of the art, is very much *ad hoc*. A chapter is devoted to the application of perturbation theory to the analysis of non-linear systems slightly disturbed from the normal, the application considered being a ballistic trajectory. This is an important technique used to good advantage in many branches of analysis and its introduction here is very appropriate.

Leaving the problem of the analysis of a known system the book goes on to study the design of systems for which the performance criteria are expressed in terms of integrals of the controlled variables and then to study "optimalising controls," where the control system continually senses and measures, and no exact knowledge of the properties of the controlled system is necessary. This is an ideal form of control in which the optimum point of operation is sought out and the system kept in the neighbourhood of this point. To the practical engineer the principle behind the last two chapters will appeal; systems are considered into which a certain amount of flexibility and adaptability is built so that incidental and unexpected mistakes in design will be automatically corrected by the control itself without human aid. The implication of reliability of equipment and the problem of obtaining satisfactory performance in spite of system errors are discussed. This problem is, of course, very often faced by circuit duplication or triplication, but it is being systematically studied by von Neumann and an interesting summary of his work is given. This theory, it should be stated, is still in its infancy and does not as yet offer any assistance in problems of control engineering.

In conclusion, this book was found to be very interesting and well produced. It is of considerable significance to those engaged in control engineering and specifically identifies a subject which, to date, has been scattered around the technical journals of many branches of science and engineering. It serves a very useful purpose if it does nothing but bring together the accumulated thoughts and experiences of engineers in different branches of what we now recognise as the same subject.

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

TRADE EXHIBITIONS

SIR,—Increasing the popularity of British trade exhibitions is of value in developing both home and export markets.

Having just returned from visiting the Hanover Trade Fair, at which attendance was phenomenal, may I refer to some of the features which I feel were responsible for its great success.

First, the Fair was international in scope, with separate halls for different classes of products. Secondly, a complete block was given over to facilities for oversea visitors, including a reception point, special restaurant, accommodation bureau and a general information service. Thirdly, there were many features to attract the general public—in fact, the week-end I was there the whole of Hanover seemed to be attending; amenities included attractively laid-out grounds, with orchestras, restaurants, open-air cafés, open-air dancing, &c.

Naturally, the limitations of halls such as Olympia and Earls Court do not permit facilities on such a scale; but could not an alternative site be found as a permanent home for our major exhibitions—attractive alike to businessmen and the general public in England and from abroad?

H. C. LANGRICK
Director and General Manager
Byron Business Machines.
Nottingham, May 31st.

RESILIENCE OF A GYMNASIUM FLOOR

SIR,—The conventional gymnasium floor is formed with narrow planks of special timber carried on light joists which are supported at fairly close intervals by pads of rubber or special felt resting on the concrete foundation. The resilience of the floor depends chiefly upon these elastic pads. A floor with an equally good surface can be formed with wood blocks or granwood blocks resting direct upon the concrete base. This floor, though having an equally good surface, has virtually no resilience at all.

The former is considerably more expensive than the non-resilient floor and is usually asked for by teachers of physical education. In view of the considerable difference in expense, it is desirable to determine whether the preference for the resilient floor is based on measurable physical properties or is purely psychological. The essential physical difference between the two floors is that the former yields slightly to the shock of a child landing on it or jumping or running. This yield is almost completely absent from the rigid type of floor.

In order to judge the effective value of the yield of the floor as compared with the natural resilience of the child's limbs experiments were made on a first-class gymnasium floor at Taunton's Grammar School, Southampton. Dr. Wright and Mr. Ray, of Civil Engineering, Southampton University; Miss Ricks and Mr. Davies, Organisers of Physical Education; Mr. G. R. Carter, Senior Physical Education Master of the School, took part in the experiments.

A light rigid girder some 15ft long was rested on blocks at its ends with sand bags to hold it steady. The centre of the girder carried a dial gauge, which showed variations in the distance between the fixed girder and a point on the floor below it.

A boy, weight 150 lb, jumped from a box 3ft 6in high to land on the floor close alongside the dial gauge. In a number of tests the yield of the floor as shown by the dial gauge varied from 25 to 30 thousandths of an inch (0·025in to 0·030in). An approximate measurement of the distance his hip came down after his feet touched the ground showed about 6in. The shock upon his body depends inversely on the distance in which its fall is arrested. As the yield of the boy's limbs was 200 times the yield of the floor it is difficult to believe that the resilience of the floor has any significant physical value whatever.

In the case of a child's head or knee hitting the floor in an accident the mass of the bone is so small by comparison with that of a small surrounding area of the floor that the deflection even of a resilient floor can only be minute. In that case softness of the floor surface is the valuable quality.

T. R. C-B-CAVE
Southampton, May 23rd.

Distribution of THE ENGINEER

THE normal arrangements for distributing THE ENGINEER to subscribers have been disrupted by the railway strike and emergency arrangements have had to be made. With the co-operation of the wholesale newsagents, most of the difficulties in the United Kingdom have been overcome. But there may be some delay in delivery. A few postal subscribers may receive, for the duration of the strike, only the editorial contents; complete copies will be sent to them as soon as circumstances permit. For the distribution of copies to postal subscribers abroad use is being made of air transport. But unfortunately delayed delivery is inevitable in certain countries.

We very much regret the inconvenience caused to readers through late delivery; and if any subscriber should find that a copy of any issue has not reached him within a few days of the date of issue, he should report the matter to The Manager, THE ENGINEER, 28, Essex Street, Strand, London, W.C.2.

Books Received

Elementary Plane Surveying. Third edition. By R. E. Davis. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 41s. 6d.

Analysis of Feedback Control Systems. By R. A. Bruns and R. M. Saunders. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 53s. 6d.

Water Supply Engineering. Fifth edition. By H. E. Babbitt and J. J. Doland. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 61s.

Elements of Servomechanism Practice. By G. J. Thaler. London: McGraw-Hill Publishing Company, Ltd., McGraw-Hill House, 95, Farringdon Street, E.C.4. Price 53s. 6d.

The Science of Petroleum. Vol. V, Part III, *Refinery Products.* By B. T. Brooks and A. E. Dunstan. London: Oxford University Press, Amen House, Warwick Square, E.C.4. Price 126s.

Organic Reagents for Metals. Fifth edition. Edited by W. C. Johnson. Published by Hopkins and Williams, Ltd., Freshwater Road, Chadwell Heath, Essex. Price 15s.

A Treatise on Surveying. Sixth edition. Vol. I, *Instruments and Basic Techniques*; Vol. II, *More Advanced Techniques and Modern Developments.* General editor. W. Fisher Cassie. London: E. and F. N. Spon, Ltd., 15, Bedford Street, Strand, W.C.2. Price 32s. 6d. each volume.

Preservation of an Early Horizontal Steam Engine

By W. B. STOCKS

HORIZONTAL engines have not, perhaps, made the same appeal to students of steam engine archæology as the more picturesque beam engine. Nevertheless they have an interesting place in steam power development and possess the added advantage of comparative simplicity and absence of bulk when the museum preservation of an antique specimen is under consideration. The writer has recently had the good fortune of being actively concerned in the discovery, restoration and preservation of a single cylinder steam winding engine which is almost certainly over a century old and is of unusual design. For many years this engine was used for the haulage of standard gauge railway wagons at the Fieldhouse Brickworks, near Huddersfield, but, at the time of discovery, had lain derelict since before the war. In 1947, shortly after they had become aware of the engine, Mr. A. J. Brooke and the writer, with the permission of the Leeds Fireclay Company, made a detailed examination and report, which was submitted to the South Kensington Science Museum. Keen interest was expressed in the various unusual features presented and the Museum's opinion was that the engine was built about 1850 and was probably the work of a local millwright.

In 1951 the Leeds Fireclay Company sold the Fieldhouse Works site to the Huddersfield Corporation and the majority of the machinery and installations were dismantled for scrap. The company, however, very kindly offered the engine for preservation if the writer could arrange for a museum to accept it. After discussion it was arranged for the engine to go to the Tolson Memorial Museum, Huddersfield, and to be set up on a concrete foundation in the surrounding park, protected from the weather by a tiled roof supported by four timber posts. It was evident that considerable restoration would be required to fit the engine for public exhibition and it was with considerable appreciation that the museum authorities, the writer and his friends, received an offer from Thomas Broadbent and Sons, Ltd., Central Ironworks, Huddersfield, to undertake the restoration and transport involved, as a gift to the town. The writer, who is employed at Central Ironworks as a foreman, was given full charge and direction of the job and permission was given for a small team of enthusiastic volunteers to enter the works during non-working hours and work on the engine.

The design has several unusual and noteworthy features (Figs. 1 and 2) most prominent of which is the layout of the cylinder in relation to the crank. The cylinder is completely reversed with the piston rod working away from the crankshaft. The tail end of the piston rod works through a bushed steadier bracket and carries a forged crosshead, secured by a flat cotter, part way on its free length. From the extremities of this crosshead works a double connecting rod, passing up both sides of the cylinder, uniting by a further crossbar into a gib and cotter type big-end bearing. Smaller gib and cotter bearings are found at the twin small ends of the connecting rod. The cylinder has the steam chest mounted on top at one end providing steam passages of very unequal length. The valve is the common " Dee " slide valve but is operated through a system of links and levers to a cross-shaft with a drop hand lever. The presence of this hand lever suggests that the valve was originally intended for hand operation. Actually the valve mechanism is operated by an eccentric working on to a peg part way up the hand lever. The attachment here is by a simple saddle-shaped forging and may be disengaged at will. It was interesting to discover that the main piston gland is identical with those designed by William Hedley for the " Puffing-Billy " locomotive of 1813 and is drawn up by two eye-bolts located on pegs projecting at either side of the neck on the cylinder end. The stroke is 24in by 11in bore. The flywheel is a solid casting weighing approximately 22 cwt. It has four spokes and is nowhere machined. The overall diameter is 8ft 4in and it is secured to the crankshaft by the traditional method of " staking " by four keys at 90 deg. centres. The boss is split to facilitate cooling when first cast.

Apart from certain brass fittings, i.e. cylinder lubricator, glands and bearing brasses, the engine was entirely manufactured in cast iron and wrought iron. Machining was reduced to a minimum when the engine was built. All the principal bolt holes are cored, including those for the cylinder end covers. The bed-plate consists of two overlapping cast iron plates of suitable profile and furnished with raised ribs locating loosely the feet for the cylinder casting and for the crankshaft pedestal bearing. Within these limits there was sufficient clearance in the bolt holes for the cylinder and bearing to be aligned properly and then wooden fillets were driven in between the beadings and the feet. The crankshaft bearing at the crank end is actually on the bed-plate, whilst the outer bearing has its own foundation. Originally there were three bearings and an extended crankshaft with a geared drive to the winding barrel, but for preservation purposes the shaft was shortened and the third bearing and the winding gear abandoned. The total weight of the engine is about 3 tons and the old working foundation consisted of two massive pitch pine baulks, square section, securely bolted together. These were discarded when it was decided to lay down a new concrete bed at the museum.

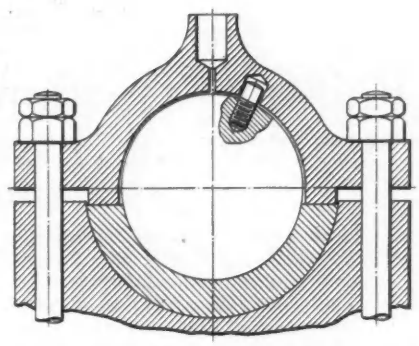


Fig. 3—Locking peg in crankshaft bearing, concealed in cap, but easily removable if required

Restoration raised several interesting queries for which there was no hard precedent, such as how far to replace worn parts without destroying the outward and obvious signs of age, and how to lock the engine against the possibility of children

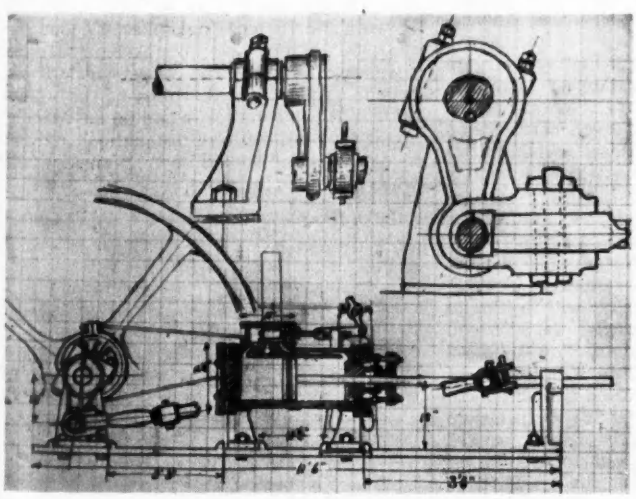


Fig. 1—A page from the author's sketch book made while the engine was being reassembled in the works

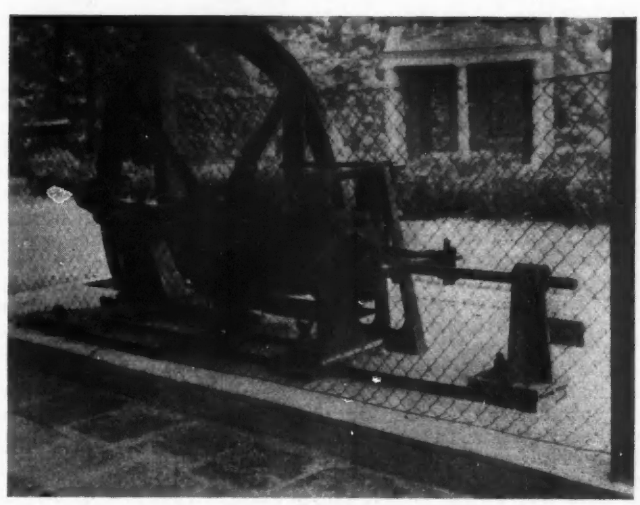


Fig. 2—The restored engine after reassembly for exhibition in the museum park

turning it by climbing on the flywheel spokes. The latter seemed a very real danger in view of the situation in a public park, though we did not want to immobilise the engine permanently or add any apparent lock. This difficulty was finally solved by drilling and tapping the crankshaft and screwing in a dowel peg (Fig. 3). This is concealed beneath a bearing cap which has had a blind hole drilled to accommodate the peg. The engine can be freed in a matter of moments by removing the appropriate cap and unscrewing the steel peg.

The engine has been painted green generally, whilst those parts which would normally be bright have had several coats of best quality coach varnish. After twenty-four months in its new situation this finish gives promise of being very durable.

It is of interest to note that two comparable old engines exist, preserved as historical relics. One is in the York Railway Museum and the other, designed by George Stephenson, is the property of the Clay Cross Company. All three are about the same age and, curiously, were all designed for rope haulage of railway vehicles.

Of all mechanical inventions it is probably true to say that the West Riding of Yorkshire owes more to the steam engine than any other. With this in mind we regard our experiences with the Fieldhouse engine, to quote the title of our film record, as a very real " Tribute to Steam."

Railway Traction by Single-Phase Current at Industrial Frequency

No. III—(*Concluded from page 782, June 3rd*)

A convention on railway electrification at 50 c/s, single-phase, was held by the S.N.C.F. at Lille from May 11th to 14th. Recent progress in this system of electrification as revealed at the Lille convention, with particular reference to the Valenciennes-Thionville line, is described here. In the previous articles in this series we dealt with questions of power supply, fixed installations and locomotives. The final article which appears below compares the different systems of electric traction and discusses the future development of the 50 c/s single-phase locomotive in terms of two of the reports presented at the Lille convention.

TO railway engineers one of the more significant aspects of the recent conference on railway electrification by single-phase current at industrial frequency was that it invited fresh comparisons between the different systems of electrification.[1] No such comparison was possible, except on a purely theoretical basis, at the time of the S.N.C.F. conference on the 50 c/s system at Annecy in 1951, when the practical experience of the S.N.C.F. with this system was limited to that which could be derived from a small service mileage from a rectifier locomotive and a mileage of about 165,000km from an Oerlikon locomotive equipped with one a.c. commutator motor per axle. Nor was much more operating experience available at the time of the I.E.E. meeting in May, 1954.[2, 3]

At the recent convention at Lille, however, it was possible to present a clearer picture of French experience with single-phase 50 c/s electric traction. For by March 31st last the first single-phase a.c./d.c. locomotive, CC14101, had covered a distance of 180,100km and eight other similar locomotives had brought the aggregate distance for this class to 341,200km ; at the same time the first B_0-B_0 locomotive with " direct " a.c. commutator motors, BB 13001, had covered 151,500km and two other similar locomotives brought the total for this class to 285,900km ; finally the first B_0-B_0 locomotive with ignitrons and d.c. motors, BB 12001, had covered 165,000km, while two other ignitron locomotives had raised the total for this class to 285,500km. The figure quoted for BB 12001 represents a daily average run of between 500km and 650km over a period of about 8½ months. Between October, 1954, and March, 1955, this locomotive hauled 232 trains of 1200 to 1400 metric tons. In March 1, 1955, when seven-day operating was introduced for C_0-C_0 locomotives, they hauled 186 trains of more than 1700 metric tons. Figures such as these provide a practical basis for the comparisons between the various systems (25kV, single-phase 50 c/s, single-phase 16⅔ c/s and 3000V d.c.) made in Monsieur Garreau's report.[1]

The comparisons are based on a study made of the North-East system of French Railways, covering a length of 2890km of line including loop lines. This system consists, broadly, of radial links between Paris and Boulogne, Lille, Aulnoye and Strasbourg, and transverse links, of which the main one is Calais-Lille-Valenciennes-Thionville-Strasbourg. Except between Valenciennes and Hargarten, which includes gradients of 1 in 100, the profile, generally, is not difficult.

The traffic over this system is considerable, but the density varies widely. Taking an arbitrary figure of 1·0 to represent the traffic density over the S.N.C.F. as a whole, the comparative figure for the North-East system as a whole is 3·5. The corresponding figures for various parts of the North-East system are Paris-Epernay 7·0 over a distance of 141km, Epernay-Lerouville, 6·0 over a distance of 147km, Epernay-Charleville 1·2 over 116km, and Amiens-Calais 1·4 over 273km. Comparable figures on other systems are, Paris-Orleans 8·0 and Paris-Lyons 6·0.

The studies on the North-East system were based on the existing traffic, no allowance being made for future growth. On the power supply side account was taken of projected extensions and developments on the Electricité de France network, which were to a large extent independent of railway requirements. Provision was made for modifications arising from overhead bridges and forty-eight tunnels with a total length of 26·428km. In comparing the various systems of electrification the basic assumptions with regard to main line locomotives was that the axle load should be 20 metric tons, to allow common use over the whole system. Three types of locomotives were considered : B_0-B_0 locomotives for high-speed passenger trains up to 140 km.p.h.; B_0-B_0 locomotives for mixed traffic with a maximum speed of 140 km.p.h.; and C_0-C_0 locomotives specially designed for hauling heavy goods trains with maximum speeds up to 60 km.p.h. A requirement of the passenger locomotives was that they should be capable of starting and hauling a 700-ton train up a gradient of 1 in 120, which is the steepest gradient between Paris and Strasbourg. No similar requirement was stipulated for goods services, since the load of some of the trains was governed by other considerations than the capabilities of the locomotives.

In the case of the B_0-B_0 locomotives the comparative studies were based on the S.N.C.F. practice of providing for an accelerating effort of 3 kg per metric ton, giving an acceleration of 2·8cm per square second, the corresponding coefficient of adhesion being 0·282, figures which postulate the use of current conversion and d.c. motors. With single-phase 16⅔ c/s direct-motor locomotives an acceleration of 8cm per square second was assumed, with a coefficient of adhesion of 0·26. With 3000V d.c. locomotives using 1500V d.c. motors, and mechanical parts similar to the 50 c/s locomotives now in service, a coefficient of adhesion of 0·2 was assumed.

On this basis the initial costs of the various locomotives are given in Table I, all the figures being in millions of francs.

TABLE I—*Initial Costs of Locomotives*

	50-cycle single-phase	16⅔-cycle single-phase	3000V direct current
BB 120km/h	26,518	18,677	19,921
BB 140km/h	6,318	6,137	6,137
CC without regenerative braking	—	22,710	17,196
CC with regenerative braking...	8,815	4,742	4,015
Total	41,651	52,266	47,268

The considerations governing the cost comparisons for power supply, substations, catenaries, signalling, telecommunications, and alterations to lighting and motive power installations required for the various systems of electrification are given in the report by Monsieur Garreau.[1] His conclusions are summarised in Table II, from which it will be seen that there is little to choose between the systems from the viewpoint of initial costs.

TABLE II—*Summary of Initial Auxiliary Costs (Millions of Francs)*

	50-cycle single-phase	16⅔-cycle single-phase	3000V direct current
Signalling	3989	3989	4324
Telecommunications	3049	2734	2809
Lighting and power	2095	2095	1828
Total	9133	8818	8961

The components making up the initial costs of electrification by the various systems are summarised in Table III, from which it will be seen that there is little difference between the 16⅔ c/s single-phase system and the 3000V d.c. system. A considerable advantage lies with the 50 c/s single-phase system. Indeed, on the basis of the source quoted[1] this advantage in capital cost saving applies to both the fixed installations and the locomotives and should be maintained if and when the traffic increases.

TABLE III—*Summary of the Main Initial Costs (Millions of Francs)*

	50-cycle single-phase	16⅔-cycle, single-phase with		3,000V d.c.
		Distributed conversion	Centralised conversion	
Power supply ...	6,884	18,511	19,623	19,206
Catenary	50,076	48,472	48,622	54,922
Total fixed installations	56,960	66,983	68,245	74,128
Locomotives ...	41,651	52,266	52,266	47,268
Grand total ...	98,611	119,249	120,511	121,396

Operating and maintenance costs are also considered in Monsieur Garreau's report[1] in which tabulated statements are given under the

headings of locomotive maintenance, energy costs, including operation and maintenance of supply points, substations and catenaries. These annual operating costs are summarised in Table IV.

TABLE IV—*Summary of Annual Operating Costs (Millions of Francs)*

	50-cycle, single-phase	16⅔-cycle, single-phase with		3,000V d.c.
		Distributed conversion	Centralised conversion	
Operation and maintenance of the feeding installations	100	150	195	190
Maintenance of the catenaries	768	768	768	920
Locomotive operating and shed expenses	3,498	3,816	3,816	3,656
Maintenance of locomotives	1,803	2,028	2,028	1,932
Power cost	5,730	6,840	5,950	6,050
Total	11,899	13,602	12,757	12,748

Again it will be seen that the total operating costs are lowest in the case of the 50 c/s single-phase system ; they are approximately equal for the 16⅔ c/s single-phase and the 3000V d.c. systems.

Finally, the conclusions reached, on the basis of the assumptions made in the report,[1] are summarised in Table V, in which the costs of the various systems are expressed as percentages of the costs of the 50 c/s single-phase system.

TABLE V—*Summary of Costs Expressed as Percentages of Costs of 50 c/s Single-Phase System*

	50-cycle, single-phase	16⅔-cycle, single-phase, with		3000V d.c.
		Distributed conversion	Centralised conversion	
Principal initial costs of fixed installations	100	117	120	130
Initial costs of locomotives	100	125	125	113
Total initial costs	100	121	122	123
Annual operating expenditure	100	114	107	107

Future Developments

The future development of 50 c/s single-phase locomotives was considered in the final paper[4] of the S.N.C.F. convention at Lille. To meet the need for fast trains like those used on the Paris-Lyons service, provision is being made for locomotives with a normal operating speed of 140km.p.h. and an output exceeding 4000 h.p. For the Paris-Lille service, therefore, the locomotive programme consists of an initial series of fifteen high-speed ignitron locomotives and two high-speed B_0-B_0 locomotives with "excitron" rectifiers and only two traction motors—one per bogie. These two excitron locomotives with dual frequency equipments are suitable for single-phase operation at 50 c/s or 16⅔ c/s.

The new high-speed ignitron locomotives will be designed for a maximum speed of 160 km.p.h. They will be suitable for hauling passenger trains of 700 metric tons between Paris and Lille (where there is a limit of 140 km.p.h.) at an average speed of 120 km.p.h., allowing for two intermediate stops. On the same route they will be capable of working goods trains of 2000 metric tons at an average speed of 66 km.p.h., the speed limit being 100 km.p.h. The weight of the electrical equipment will be 38·7 metric tons. A measure of the progress achieved in these designs, in a period of about two years, is given by the fact that the new locomotives will have a power-to-weight ratio of 39·3 h.p. per metric ton, compared with the corresponding figure of 48 h.p. per metric ton for the present B_0-B_0 locomotives used between Valenciennes and Thionville.

The two new excitron locomotives will have a single motor on each of the two bogies. The electrical equipment on each locomotive will weigh 36 metric tons (two motors weighing 12·4 metric tons, compared with four motors weighing 13·6 metric tons). The performance will be of the same order as that of the ignitron locomotive.

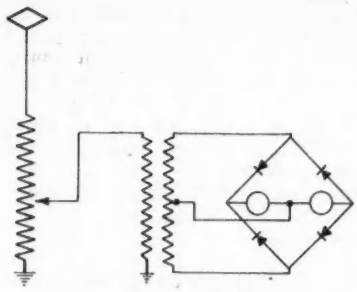


Fig. 6—Diagram showing the principle of a two-motor locomotive with Graetz layout

Another development is towards the use of lightweight B_0-B_0 locomotives which would be specially suitable for lines carrying less heavy traffic than that which is typical of the Valenciennes-Thionville line. Locomotives are envisaged with total weights of 57 metric tons (one motor per bogie) and 60 metric tons (two motors per bogie). It is proposed to use the Graetz connection (Fig. 6) to supply the d.c. motors. In this method, as developed by Alsthom, the common point of the two motors in series is connected to the mid point of the transformer secondary winding. This arrangement preserves the tractive advantages of motors connected in parallel.

Developments envisaged in locomotives equipped with 50 c/s commutator motors include improvements in the design of four-motor equipments. The use of resistive connections absorbing about 3V is foreseen. The effect of resistive connections is likely to be enhanced by fitting grooved brushes and three-section brushes with insulated casings and with special composite heads to reduce the current in the segments short circuited by each brush. Special arrangements for cooling the commutator are under consideration—they include the fitting of cooling fins on the V-clamping ring. The possibilities of locomotives with one motor per bogie are also being studied.

REFERENCES

[1] M. Garreau : "Comparison between the Various Systems of Electric Traction," S.N.C.F. Convention, Lille, May, 1955.
[2] M. Garreau : "Electric Traction Using 50 c/s Current," *Proc. I.E.E.*, Part I, No. 131, 101, September, 1954.
[3] F. Nouvion : "Electric Locomotives on the Valenciennes-Thionville Line," *Proc. I.E.E.*, Part I, No. 131, 101, September, 1954.
[4] F. Nouvion : "The Development of 50-cycle, Single-Phase Locomotives in the Near Future," S.N.C.F. Convention, Lille, May, 1955.

New Rules for Expert Evidence

By SIR WILLIAM VALENTINE BALL, O.B.E.

IT may not be generally known that expert witnesses in general, and certain types of "expert" in particular, are affected by certain recent changes in the rules of the Supreme Court. Until last October it was competent for either party to an action to summon any number of expert witnesses to support his case. This is a privilege conferred by no statute : it forms part of the common law. From time immemorial it has been the duty of a judge to hear all the evidence : it was never competent for him to limit the number of witnesses in any way. And so, in the old days, it was common enough to see many experts in attendance at court, especially when a patent case was under consideration. Men of great distinction were often called. I can remember hearing (*inter alios*) Lord Kelvin, Sir James Dewar and Professor John Hopkinson being cross examined on many occasions when I was a young man at the bar. Of course, a judge, having heard the evidence of one expert on a particular point, might always, during the course of a case, intimate that he was satisfied by the evidence of that expert on one point, and so make it obvious to counsel that to call any other witness would be superfluous. But he has no power to refuse to hear a witness.

Now, however, a rule of court which came into force last year provides for a possible limit to the number of experts. Before stating the rule, let me premise that certain questions of procedure in a particular case may be decided either before the trial by a master of the Supreme Court on the hearing of what is called the "summons for direction," by a master, or by the judge at the trial. The new rule (O.37, *r.* 1C) provides that "the Court or a Judge may, at or before the trial of an action order or direct that the number of medical or expert witnesses who may be called at the trial shall be limited by the order or direction."

Normally orders of this kind are made at the instance of one of the parties, but it is specially provided (by O.30, *r.* 3) that an order to limit the number of experts may be made by the Court of its own motion. And so, strange as it may appear, an order may be made, e.g. to the effect that only one expert witness shall be called at the trial by either party, and this without there being any suggestion that either party desires the limitation. Whether any master or judge will be, shall I say, bold enough to adopt this course remains to be seen. I can only say that were I called upon once more to exercise the functions of a master, I should be long sorry to make such an order in the absence of an application by one or other of the parties, and only then after hearing argument on both sides.

So much importance may attach in a particular case to the evidence of experts, that if any attempt is made to limit their number at an early stage of the case (e.g. on the summons for directions) the party objecting should ask that it be adjourned for special consideration by the master, or to the judge at the trial.

But how, even in these circumstances, is the question to be answered ? In the normal way, witnesses are called before the Court, on the advice of counsel, after the issues are clear, counsel is asked to advise on evidence. He will decide what witnesses are to be called ; and he may (or may not) think it necessary to have before him a proof of the evidence of one or more experts bearing upon a vital point in the case. He may come to the conclusion that in certain circumstances, which may be only revealed at the trial, it will be necessary to call two or more experts. Thus the evidence of Pro-

fessor A may carry the case a certain distance, but that of Mr. B. and Mr. C. will be necessary to prove the case up to the hilt. How can he, in the interests of his client, submit to any order limiting the number of experts ? Would the judge at the trial, who knows nothing of all this, be doing justice if he made an order to the effect that but one witness shall be called ?

And suppose the judge is minded to make a limitation order, must counsel explain, in the presence of his opponent, why he considers that more than one expert is necessary ?

I mention this in order to show how dangerous it is to interfere with the common law rule which enables a party to present his case in whatever way he chooses. And here I would point out that what may be a vital change in the rules of evidence has been brought about, not by an Act of Parliament, but by a Rule of Court made by a statutory committee whose powers are (to all intents) limited to regulating the procedure and practice of the Supreme Court, and who are certainly not empowered to vary the rules of the common law.

Upon what was the Rule Committee founding when it made this new rule ? It might be thought that they were influenced by the findings of a strong committee presided over by the Master of the Rolls, whose final report on Supreme Court Practice and Procedure was published in July, 1953.

In that lengthy document the committee dealt with many things, including expert evidence, but they did not suggest that the Court should be able to place a limitation on the number of experts who might be called in a particular case.

So much, then, for the new rules which affect all expert witnesses. But there is one rule which particularly affects engineers : not engineers generally, but certain engineers who are called as experts in a particular kind of case. Let me state the limitation at once : it only concerns an engineer called or to be called as a witness in a case arising out of an accident on land due to a collision or apprehended collision. " Collision" is not defined ; but it is fairly obvious that it means collision with another car. If my car skids and ends, bottom uppermost, in a ditch, would that be a " collision " ? There is room for doubt on the question.

Let me outline what normally happens in a collision case. The question being " What caused the disaster ? " The plaintiff asks an engineer to examine the vehicles concerned, and the *locus in quo*, and to make a report which can (*a*) be put before counsel when he advises on evidence ; which (*b*) constitutes the " proof " of the witness when called, and (*c*) is a confidential document which cannot be revealed to " the other side." In recent years, however, a very reasonable practice has grown up which lessens the cost of litigation. The parties endeavour to agree a report of an engineer, and further agree that, if this is impossible, the expert evidence shall be limited, say, to one witness on either side. I made many an order in that form when I was a Master of the Supreme Court.

But that does not satisfy the reformers ! A new rule (O.37, *r.* I.E.) provides, in effect, that in any case of the limited class to which I have referred to—unless the Court otherwise orders—an engineer called as an expert about motor vehicles cannot give oral evidence at all unless a copy of a report by him containing the substance of his evidence has been made available to the other side before the hearing of the summons for direction and an order made on that summons authorises the admission of the evidence.

There is nothing like this anywhere else in the Rules of Court. Observe that it is of effect unless the Court of a Judge otherwise orders. This means that on the summons for directions, he who desires to claim that the report of his engineer is privileged, from production must make an application to that effect forthwith. Note, too, that the rule insists on the engineer making a report. If he does not he cannot be called as a witness at all. Yet there are many cases where the cause of a collision is so obvious as to require nothing but a verbal report. Is a party, nevertheless, to be precluded from calling him as a witness ? The answer to that question is yes.

One thing is plain : if ever an engineer is called to make a report in relation to a collision case, on the part of the plaintiff, he should be warned that it is a document which will certainly be shown to the defendants' advisers. Result : it may have to be so framed that it will bear only a resemblance to the document which he would prepare as technical adviser to the plaintiff. In such a case he would be careful to say that " while his opinion was " so-and-so, " it must be borne in mind, that the facts are consistent with another view." Indeed, he might be compelled to say in his report that he could not attribute the accident to the negligence of the defendant, and suggest a compromise.

It is plain, therefore, that the engineer consulted as an expert in a collision case will have to be warned that anything he writes in his report may have to be produced to those who are advising the other side. In these circumstances he will be inclined to sign a document which may be of little or no value to those who are looking to him to help them to meet and overcome the difficulties of the case.

Automatic Moulding Machine

AN entirely automatic moulding machine capable of a production rate of 240 half-boxes up to 34in by 20in by 10in per hour was recently demonstrated by Coleman and Wallwork, Ltd., 32, Victoria Street, London, S.W.1. Mould ramming operations are controlled by electronic timers which enable the jolting, squeezing, simultaneous jolt squeeze and vibration times to be accurately set for any particular kind of mould. Pattern plates can be conveniently changed and there is a complete set of manual controls to facilitate this operation.

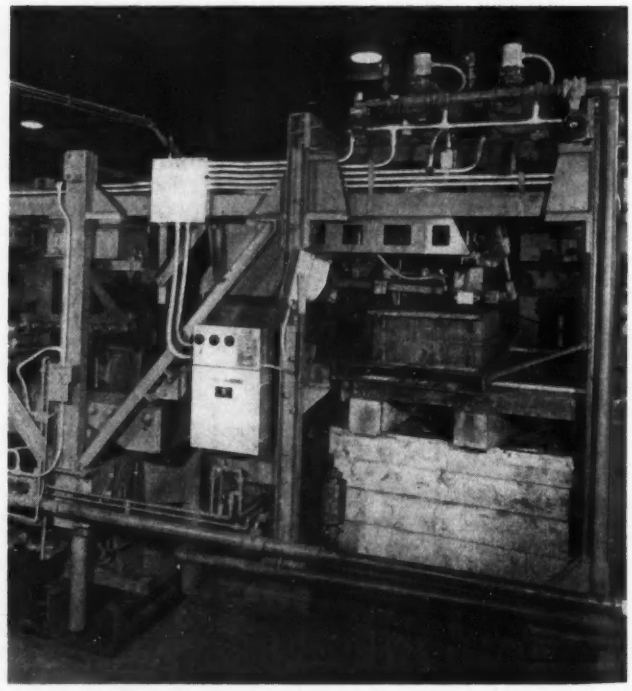
The machine is primarily designed to work in a mechanised foundry unit with empty box, sand and mould removal facilities, utilising two moulding units, one operating on the bottom half and the other having additional facilities for upturning the top box. The operation of the moulding unit can be broken down under five different stations at all of which operations proceed simultaneously. The maximum length of time required at any one station is fifteen seconds, including transfer times.

The arrival of an empty box on the conveyor of the moulding unit breaks the beam of a photoelectric cell which can be seen in our illustrations. The complete cycle of operations at each station is thus initiated. Pneumatic pawls attached to an overhead trolley mechanically pick up the empty box from the mould conveyor and the trolley moves to the second station where the box is deposited. It is here aligned by a pneumatic ram for transference by the overhead trolley to the mould-making station. The stripping frame is then lowered and the box located on the pattern pins. After a short preliminary jolt to settle the box properly on the pins a weighed quantity of sand from an overhead hopper is deposited in the box. Because of the restricted ceiling at the maker's works, the sand hopper is not shown in our illustration.

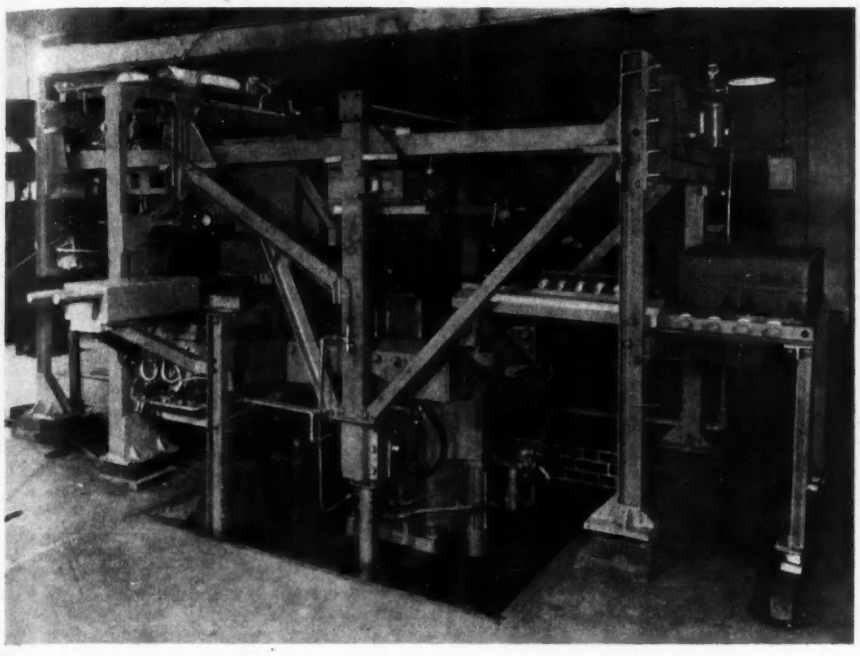
The machine then commences to free jolt, subsequently the pressure head moves into position and the machine commences to jolt and squeeze. Finally, the squeeze piston is exhausted, the pattern vibrated, and then removed from the mould. The next operation depends on whether the machine is working on top or bottom boxes. After the moulding unit has been cleared the pattern plate is pneumatically cleaned and sprayed with parting fluid.

At the fourth station top boxes arrive joint face down and the two edges of the box resting on special edge rollers attached to a pneumatic vertical lift cylinder. Air is exhausted from this cylinder leaving the mould suspended by the box trunnions, which are rotated by a rack and pinion through 180 deg. The edge rollers are then raised again to lift the mould off the trunnions and present it to the transfer unit.

This consists of two arms connected by a mechanical linkage to a vertical pneumatic cylinder mounted on an overhead trolley. The trolley is moved in a horizontal direction by a further pneumatic cylinder. At a given signal the arms engage the mould, lift and move it across to a position immediately above the centre line of the mould conveyor. When the centre of the mould coincides with the centre of



Automatic moulding machine with the arrival station on the right and showing the photo-electric cell on a column (centre)



From the opposite side of the machine, the light source of the photo-electric unit is seen on the extreme left, and bottom boxes are shown at each station. The alignment rams are in the middle left

one of the pallets on the conveyor, the vertical cylinder is exhausted and the mould is gently deposited on the moving conveyor. The arms continue downwards until they are well open and clear the box, when they are lifted and the trolley retracted to its original position.

The whole automatic unit is contained in a substantial fabricated steel frame, bolted and dowelled together, and ready for setting on previously prepared foundations.

The feeder belt assembly is mounted beneath the sand storage hopper and underneath is an automatic weighing hopper with pneumatically operated discharge doors. This hopper is balanced on knife-edges attached to a weighted yard arm. The position of the weight is set such that when the charge of sand in the hopper weighs a predetermined amount the yard arm lifts and trips the limit switch, which automatically stops the feeder belt from rotating and discharging further sand.

The automatic control system depends on a separate wall-mounted, multi-stage electronic timing unit equipped with all necessary safety interlocks and with each operation individually adjusted by dial turning to give times between 0·25 and 10 seconds. The timer in turn energises solenoid-operated pneumatic control valves which admit compressed air at 85 lb per square inch to the various operating cylinders of the machine. The maximum useful load on the moulding unit is 1000 lb, the squeeze pressure is 17,000 lb, and the air consumption per half-mould is 50 cubic feet.

Kandla Port Project

BY OUR INDIAN CORRESPONDENT

INDIA'S 4000-mile-long coastline had, before partition, only six major ports, namely, Calcutta, Visakhapatnam and Madras on the east coast, and Bombay, Cochin and Karachi on the west coast. Even as far back as 1946 the necessity was felt for an additional major port on the coast of Kathiawar and Kutch, as the hinterland which the Bombay harbour served was too large. With the partition of the country in August, 1947, this need for an additional major port on the west coast was felt more acutely in India, as Karachi was now in Pakistan. More than a third of the hinterland which Karachi had been serving had now to use Bombay. The Government of India then appointed a committee to investigate " the necessity or otherwise of a deep sea port on the stretch of coast covering Kathiawar and Kutch for the accommodation of ships of large size and tonnage in all seasons of the year, and where it should be sited." The committee considered that a port was necessary and Kandla, already a minor port, was suggested as a suitable site.

Kandla is situated on the south coast of Kutch at the eastern extremity of the Gulf of Kutch, where there is a wide creek running north-south providing an excellent sheltered site with depths of water ranging from 30ft to 55ft for a distance of about 8 miles from its junction with the Gulf. The late Maharao of Kutch had built a minor port in 1930. It is around this nucleus that the present development for converting Kandla into a major port was recommended to take place. As is usual with estuarine rivers and creeks, there is a bar at the entrance where a minimum depth of 13ft is available at the lowest tide. Ships with draughts above 13ft will therefore require to be piloted. Taking into account this minor limitation, the advantages of siting a major port at Kandla were decisive. The provision of rail facilities was taken up first and work was begun early in 1949 on the construction of a metre-gauge link from Deesa to Kandla, a distance of about 172 miles. The link, which was opened for traffic on October 2, 1952, established a connection to Kandla port with the metre-gauge system from Ahmedabad to Delhi.

After the collection of sufficient data for preliminary design, world tenders were invited in November, 1950, and the contract was awarded to McKenzies Heinrich Butzer (India), Ltd., a combine of West German and Indian contractors, for a sum of about Rs.62,500,000 (about £4,700,000). The plans which have emerged as a result of those originally submitted by this firm and the alterations incorporated on the advice of a tender committee are shown in the accompanying illustration ; they call for :—

(i) A cargo jetty 2700ft long, providing for four deep-water alongside berths for 600ft-long ships, including three transit sheds, each 450ft by 140ft, four warehouses at the back of the transit sheds, each 500ft by 120ft and open stacking grounds close to the quay. The quay will be 75ft in width. The jetty is supported on reinforced concrete hollow piles 20in outside diameter. There is no rock anywhere on the site within a depth of 230ft, the borings having revealed a soft silty and clayey soil up to about 40ft and then layers of silt and sand of varying proportions and grain sizes, and in varying states of compactness.

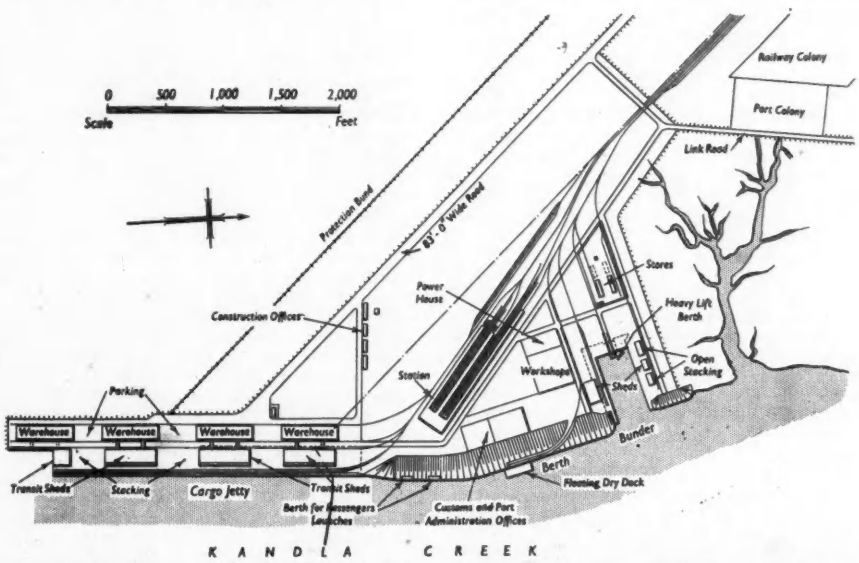
(ii) A basin or " bunder," as it is called, suitable for accommodation of lighters and sailing vessels, 500ft by 300ft in size. On the south side of the bunder is a lighter wharf equipped with light cranes. The north wharf is intended exclusively for sailing vessels, i.e. country craft. There is also a heavy lift berth for unloading heavy cargo up to 60 tons from ships in moorings.

(iii) A floating dock berth, 265ft long by 65ft wide and 24ft deep, capable of taking ships not exceeding 240ft in length and of displacement of not more than 800 tons when empty.

(iv) An oil jetty for handling oil tankers up to 20,000 tons capacity. It consists of three circular dolphins of reinforced concrete shells filled with sand and light concrete and sunk under compressed air to suitable depths. This jetty is to the north of the bunder and is not shown in the plan. The dolphins are spaced about 100ft centre to centre and are connected by prestressed concrete bridging spans.

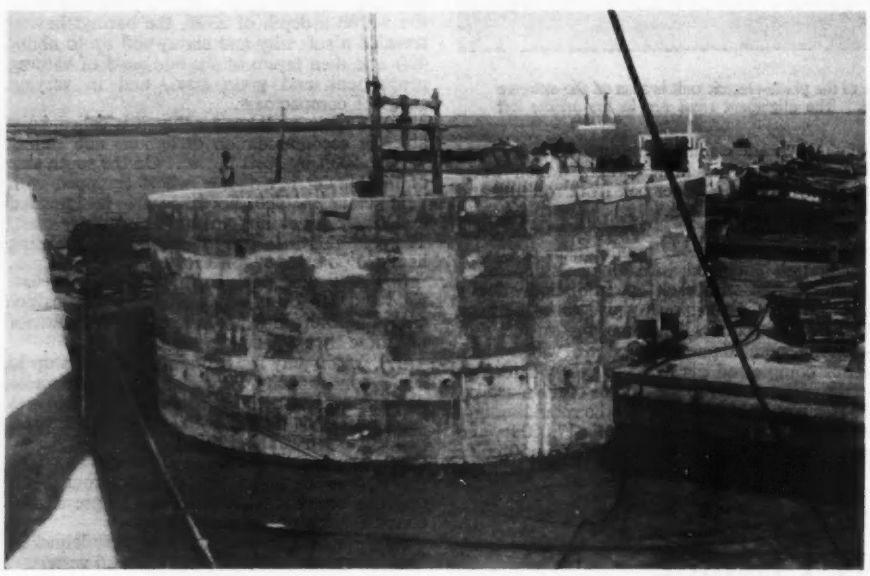
(v) A passenger berth for passenger launches. This is intended only for small coastal vessels.

These are the main works which comprise the present port development. Other ancillary works such as reclamation of the port area, shore protection, &c., are also included in the main contract. The principal port equipment consists of quay cranes, of which there are twenty-one, all on the cargo jetty, distributed in such a way



Layout of first stage of Kandla Port project. There is also an oil jetty to the north of the area shown

Constructional work in progress in the bunder of Kandla Port



Floating caisson into position for construction of oil jetty

that each berth is provided with five cranes—four 3-ton cranes and one 6-ton crane. In addition, a 10-ton crane is provided at the southern end of the jetty. The quay, 75ft wide, provides for three railway tracks and two road tracks. There is also provision for a passenger railway station near the passenger berth. The oil installations of the various oil companies are about 6 miles from the oil jetty, and a double oil pipeline, 12in and 16in in diameter, is being installed at present, provision being made for future extension of two more similar lines. A booster station with four diesel pumping sets of about 500 tons per hour capacity each is being installed between the oil jetty and the installations.

The contract was awarded in March, 1953, but work did not begin until well into 1954. The most important item, the bunder, is shown under construction in the second illustration ; it is expected to be completed by June this year or thereabouts and the oil jetty about the same time. The cargo jetty will be completed in two stages, the first stage by early 1956 and the second by the end of 1956. The total sanctioned estimate for the project is Rs.129,500,000, about £10,000,000.

The completed harbour is expected to handle about 1,300,000 tons of cargo per year, half of which will be in oils. There are plans for expanding the harbour, but eventual expansion will naturally depend upon the economic development of the hinterland it is designed to serve.

First International Conference on Non-Destructive Testing

(Contributed)

FROM May 24th to May 28th the first International Conference on Non-Destructive Testing was held in Brussels. Under the chairmanship of Professor G. Homès, of Brussels University, more than 500 members, representing twenty-six countries,* assembled to discuss this wide field of industrial activity involving radiography by X-rays and radioactive isotopes, ultrasonic, magnetic and electric methods of product examination. The materials referred to were mainly metals—principally steel and aluminium—but plastics, bricks and concrete were also discussed. The members were, in the main, metallurgists, physicists and chemists, representing industrial users and equipment makers. Government institutions of the various countries, concerned with methods, standardisation and documentation were also well represented.

In radiographic testing it appears that isotope radiography is steadily replacing X-radiography above 300kV to 400kV. Below this value the use of transportable X-ray equipment, particularly in the aircraft industry and shipyards, is gaining ground. A new and interesting widening of the scope of X-ray fluoroscopy is opened by the application of the X-ray image intensifier developed originally for medical use (notably in Germany and Britain). Betatrons up to 30MeV electron energy have begun to be used for steel sections above 4in wall (U.S.A. and Germany), and there is a tendency to make this complicated equipment smaller and more easily transportable. Linear accelerators having about 4MeV electron energy will be applied shortly to the same task (U.S.A. and Britain).

Perhaps the greatest activity was shown in the development of ultrasonic testing. Both the pulse reflection type and the resonance type are being developed. Special measurements of material constants such as elasticity, damping for impurity content measurement, &c., are possible with ultrasonic methods apart from their main use for flaw detection and thickness determination. There were some references to visual inspection of opaque media with ultrasonic methods with display on the C.R. tube and one can reasonably expect to see " ultrasonic microscopes " appearing in a few years' time (U.S.A., U.S.S.R.). The U.S.S.R. report claims, using ultrasonic absorption measurement, accurate time determination of some chemical processes. Very high ultrasonic frequencies (10^8–10^9 c/s) will be used to improve resolution. An interesting colour film on N.D.T. methods was shown by the Douglas Aircraft Corporation, U.S.A., in which penetrant methods, ultrasonic methods and radiographic methods were shown as part of the company's routine production process. A particularly impressive picture was a large immersion testing tank, 50ft by 12ft by 3ft deep, in which large light-alloy plate was scanned by an automatically-propelled immersed crystal. Magnetic particle testing is becoming widespread in industry ; the U.S. report mentions about 20,000 test units in use. Eddy current and search coil methods are also being rapidly developed, notably in Germany. Magnetic inductive methods for testing steel cables on suspension railways have received attention in Belgium and Switzerland. Non-contacting thickness gauging and continuous foil-thickness measurements are being carried out with X-ray generators (U.S.A., Germany) and beta-ray isotopes (U.S.A., Great Britain). The former method lends itself for hot strip steel rolling mills ; the latter is particularly suitable for plastics, paper and aluminium. Cold steel strip can be measured with either, the limit to the isotope measurements being set by statistical fluctuations.

It is not difficult to find faults in a first international conference of this kind attempting to cope with such an enormous field. The discussions were quite inadequate to cover even a fraction of the many subjects raised and the main reason for this was that the conference consisted of a single session throughout the week. It is clear that a future conference would have to have many parallel specialised sessions to deal with the individual subjects more fully. More attention will also have to be paid to simultaneous translation. It was not easy to assess the relative importance of the various N.D.T. methods because of the common tendency in scientific meetings to stress the new processes compared with established ones. Perhaps the greatest value of the conference was the integration of all methods into a complementary series of N.D.T. processes in the service of research and production. There was no doubt about the great interest and enthusiasm shown by the members and of the advantage derived from the personal contacts they were able to make. Also, the Brussels conference produced national reports and surveys in a number of industrial countries of the state of non-destructive testing which will undoubtedly be beneficial everywhere. One interesting fact emerging from the national reports was that only the U.S.A. and Japan possess at present journals devoted to N.D.T. methods as a whole. It is to be hoped that their example will be followed by other countries so that the ever-increasing written material will be canalised and become more easily accessible.

The resolutions agreed at the end of the conference did not make it clear whether there will be other international meetings, but there was agreement on the desirability of international co-operation in non-destructive testing and also that each country should form a single national committee representative of all interested parties concerned with testing, measurement or research.

* The British Societies were officially represented by Mr. W. E. Schall.

Coal Preparation Plant at Nantgarw Colliery

The Nantgarw Colliery of the South Western Division of the National Coal Board has been extensively reorganised for an output of 4000 tons of coal a day. The whole of this output will be dealt with in a two-process plant supplied by the Fraser and Chalmers Engineering Works of The General Electric Company, Ltd.

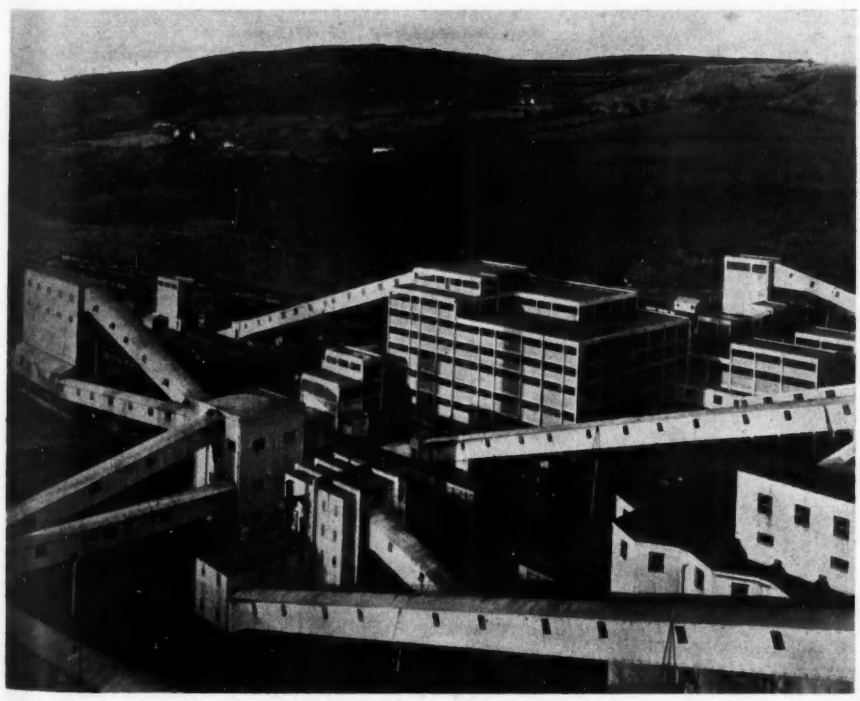
A COAL preparation plant installed at the Nantgarw colliery in South Wales, as part of an extensive reorganisation scheme, is designed to provide a high-quality coal of uniform ash content and a minimum of moisture for producing metallurgical coke. This plant is the second to be commissioned which is capable of dealing with the whole of the run-of-mine output in two processes only—heavy medium ("Chance") and froth flotation—as developed by the Fraser and Chalmers Engineering Works of The General Electric Company, Ltd., which supplied the complete plant.

For many years, in the United Kingdom in particular, it was generally the practice with the "Chance" process to treat coals down to $\frac{1}{4}$in in size after the extraction of the material below $\frac{1}{4}$in by a combination of shaker and electro-magnetically vibrated screens. The ash content of the $\frac{1}{16}$in×0 raw coal was usually low enough to allow its mixing with, say, the $\frac{3}{4}$in×$\frac{1}{16}$in coal, after the latter had been separated in the "Chance" cone, without increasing the ash content of the $\frac{3}{4}$in×0 mixture to an unacceptable value.

With the advent of mechanisation two of the most important changes which occurred in the character of the raw coal were an increase in the moisture content and an increase in the ash content, particularly in the finer sizes. In addition, the quantity of the finer sizes in the run-of-mine output increased considerably. Prior to mechanisation the free moisture content of the raw coal was, in most cases, between 1 and 4 per cent, and under these conditions it was possible to dry screen the $\frac{1}{16}$in×0 fraction from the run-of-mine output with efficiencies of between 90 and 95 per cent. It was found, however, that when the moisture content increased beyond 4 per cent the efficiency of the extraction of the $\frac{1}{16}$in ×0 fraction decreased rapidly, until at approximately 10 per cent it was virtually unscreenable by the conventional method of dry screening. In addition, the quantity and the ash content of the $\frac{1}{16}$in×0 fraction soon reached a point which precluded its being mixed back, untreated, with the washed duffs.

The designs of the "Chance" plants were no longer adequately suited to the changed conditions, and the problems involved in adapting the process to the new conditions concerned the development of some means of (1) extracting the $\frac{1}{16}$in×0 fraction from the raw coal feed when the latter had a moisture content in excess of 10 per cent; and (2) successfully cleaning the $\frac{1}{16}$in×0 fraction in a single process.

The successful surmounting of these difficulties would result in a two-process plant for cleaning the whole of the run-of-mine output from a colliery. It was quite practicable, before any investigations were made into the two-process plant, to clean an entire pit output in a three-process combination, namely, heavy medium (+$\frac{1}{2}$in, say), jig or trough ($\frac{1}{2}$in×$\frac{1}{2}$mm) and froth flotation ($\frac{1}{2}$mm×0). The two-process plant had many potential advantages, however, and it was considered that it would result in a simpler plant, lower in capital and running costs than its three-process counterpart, requiring fewer operators and, at the same time, giving better products. The reason for the last assumption was that, as the $\frac{1}{2}$in×$\frac{1}{16}$in fraction would be treated in the heavy medium section, the separation of the clean coal from its impurities would be much more accurate than in a jig or a trough washer, while it was hoped that the $\frac{1}{16}$in×0 fraction could be cleaned at least as well by froth flotation as in the two kinds of washeries just mentioned. These hopes were realised when, in addition to the advantages enumerated above, the products from the two-process plant were found to be equal to, if not better than, those from a three-process plant.



Coal preparation plant at Nantgarw

Historical

The pit has been planned for an output of 4000 tons of raw coal a day, and the entire output is brought to the surface in 3-ton mine cars, in two-deck cages arranged for simultaneous decking. The cars are discharged at the pit top by two "Plowright" rotary power tipplers, whence the flow of raw coal may be delivered either to a pair of 300-ton storage bunkers or directly to the coal preparation plant. The main purpose of the storage bunkers is to enable the different qualities of raw coal to be blended, if desired, before delivery to the preparation plant. The run-of-mine coal-handling equipment has been laid out in such a way that a third shaft, to be fitted with four cages, may be installed in the future so that the gross output from the colliery may be increased to 8000 tons a day. The diagram on page 824 shows the flow of coal through the plant.

Flow of Material Through the Plant

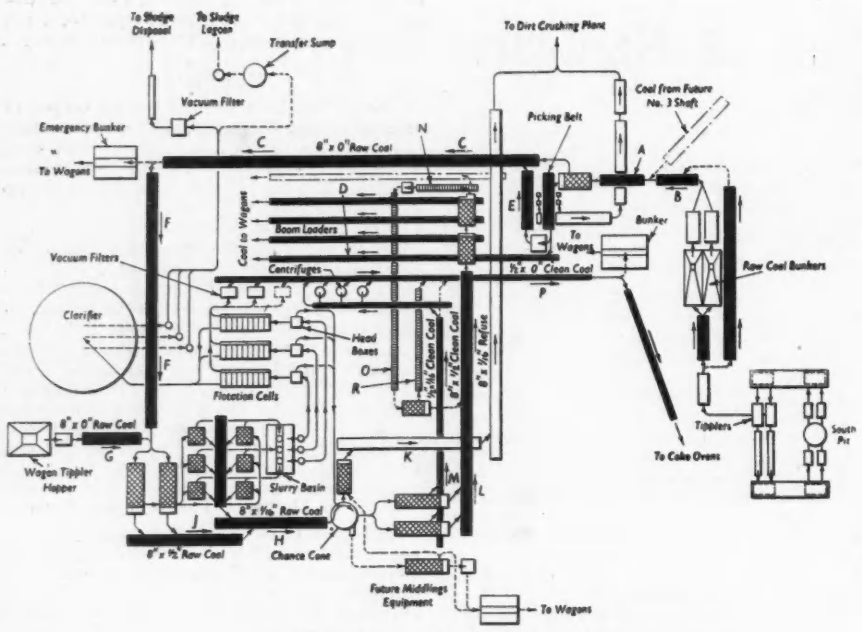
The flow of raw coal from the blending bunkers is controlled by two "Sherwen" electro-magnetically vibrated feeders which deliver the raw coal on to conveyor *A* via conveyor *B*. Conveyor *A* discharges on to the primary raw coal screen for a separation at 8in round, the −8in fraction passing to conveyor *C* while the +8in fraction is delivered on to the picking belt. At the present time the +8in coal, after hand picking, is delivered on to boom loader *D* for loading into rail wagons. Provision has been made, however, that in the future the picking belt can be fitted with a pick breaker for reducing the +8in coal to −8in. The crushed coal will then be able to join the natural 8in by 0 coal on conveyor *C*, via conveyor *E*. The facility of being able to load a +8in hand-picked coal to wagons will still be available, provision being made in the pick breaker to lift the picks clear of the belt when large coal is required.

Stone removed from the picking belt, is passed through chutes at either side of the belt and by conveyors to the stone crushing and preparation plant. All the 8in×0 raw coal passes from conveyor *C* to conveyor *F* but in an emergency it may be off-loaded to wagons through a by-pass and a 25-ton bunker. Coal loaded out in this way may be reintroduced into the plant by means of a wagon tippler and belt conveyor *G*.

Conveyor *F* delivers on to a pair of secondary raw coal screens, where the coal is separated with the aid of spray water into 8in×$\frac{1}{2}$in and $\frac{1}{2}$in×0. The latter fraction is laundered, with the aid of the spray water added on the secondary raw coal screens, to a battery of six "Sherwen" electro-magnetically vibrated screens for further wet screening into $\frac{1}{2}$in×$\frac{1}{16}$in and $\frac{1}{16}$×0. The 8in×$\frac{1}{2}$in fraction is delivered to the "Chance" washing cone via conveyors *H* and *J*, together with the $\frac{1}{2}$in×$\frac{1}{16}$in size from the screens. All the spray water, added on the secondary raw coal and screens, which contains the $\frac{1}{16}$in×0 fractions of raw coal flows into the slurry basin from which it is pumped to the froth flotation plant.

The "Chance" cone, which is 15ft in diameter, is suitable for a single-gravity separation with products of clean coal and refuse. Provision has been made, however, so that the cone can, if necessary, be converted to make a two-gravity separation for producing clean coal, refuse and middlings. A connection on the cone for the middling tube can be seen in our illustration; it has been blanked off for the time being, but the tube can be fitted in a very short time without structural alterations.

Thus even when the middlings extraction equipment is installed it will still be possible, by means of a simple operation, to revert to a single-gravity separation and vice versa. Both the upper and the lower gravities when making a three-product separation may be varied within wide limits independently of one another, while the gravity, in the case of a two-product separation, is also easily adjusted to suit the varying market requirements or the changing washing characteristics of the different coal seams.



Coal flow diagram of the Nantgarw plant

The refuse extracted from the cone is desanded and dewatered on a shaker screen and then delivered via conveyor *K* to the refuse crushing and preparation plant for ultimate pneumatic stowage underground. The clean coal is also desanded and dewatered on two shaker screens which also separate it into 8in × ½in and ½in × ⅛in. The former is delivered on to conveyor *L* and the ½in × ⅛in fraction on to conveyor *M*. Conveyor *L* discharges on to a sizing screen where the coal is separated into the following sizes : 8in × 4in, 4in × 2in, 2in × 1in and 1in × ½in. The last three sizes may be loaded into rail wagons by means of three boom loaders, while the 8in × 4in fraction can be dealt with in two ways. It can either be loaded to wagons via boom loader *D* along with the hand-picked coal ; or it can be crushed to −4in and rescreened to increase the percentage of the sizes between 4in and ½in.

The sizing screen is normally arranged for loading the wagons, but by means of a simple modification the coal can be diverted from boom loader *D* and conveyed by means of a pan on the upper deck to the far end of the sizing screen. Here it is discharged into a single roll crusher, via conveyor *N* where it is reduced to −4in. After crushing, the coal is returned for resizing via conveyor *O*. Prior to its delivery on to the sizing screen, however, the crushed coal, 4in × 0, is passed over a screen for the extraction of the −½in fraction, the latter joining the washed duff on conveyor *P*, via conveyor *R*. As already mentioned, however, the setting of the crusher can be adjusted to give a −2in product in the event of the quantity of natural 2in × 0 coal being insufficient to supply the demand of the coke ovens.

The ½in × ⅛in fraction of clean coal separated from the 8in × ½in size on the desanding and dewatering screens is delivered on to conveyor *M*. The discharge chute of this machine is arranged so that in normal circumstances the ½in × ⅛in clean coal is delivered to two of the three Rheolaveur Reineveld centrifuges for dewatering. By adjusting the valve of the discharge chute of conveyor *M*, the ½in × ⅛in clean coal may be fed directly on to conveyor *P* for disposal without dewatering.

The distribution of the feed to the three centrifuges is facilitated by means of a scraper conveyor. After dewatering, the ½in × ⅛in clean coal is discharged on to conveyor *P*, where it is joined by the ⅛in × 0 filter coke. This conveyor is fitted with a discharge chute to deliver the ½in × 0 mixture either to the conveyor feeding the coke works blending bunkers or to wagons via a 50-ton bunker.

The ⅛in × 0 fraction of the raw coal feed is laundered, together with all the spray water added on the secondary raw coal and " Sherwen " screens to the slurry basin. This basin serves as a reservoir for starting up the froth flotation plant at the beginning of a shift, besides evening out the quantity and the washing characteristics of the ⅛in × 0 raw coal before it is delivered to the flotation plant.

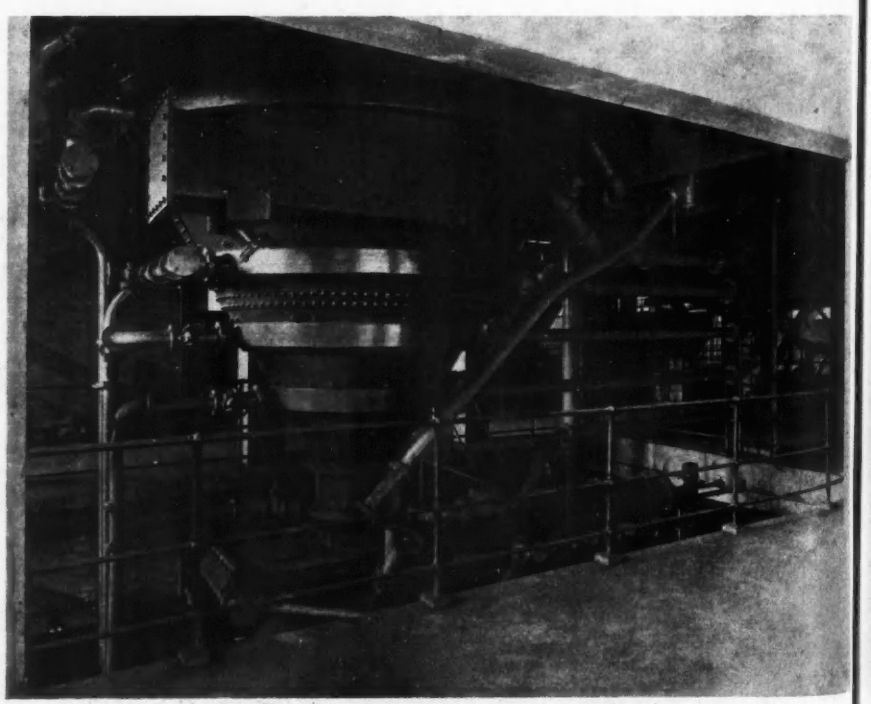
The feed to the flotation plant is controlled by means of the head boxes to which the ⅛in × 0 raw coal slurry is pumped from the slurry basin by means of three pumps. Besides controlling the volumetric flow to the flotation plant, the head boxes also separate any oversize material (i.e. above ⅛in) from the feed and deliver it to the " Chance " section of the washery. The flotation plant has a designed capacity of 60 tons an hour and consists of 628 cubic feet of flotation volume in a bank of eight " mineral separation " cells. The clean coal concentrates are laundered from the cells to two 200 square foot top feed " Unifloc " rotary vacuum filters, and, after dewatering, the filter cake is discharged on to conveyor *P* to mix with the ½in × ⅛in washed duff. The tailings from the flotation cells, meanwhile, are laundered to an 80ft diameter thickener, from which the clarified water overflows into a sump for reuse in the washery system. The thickened sludge is extracted from the centre of the thickener tank by diaphragm pumps. These pumps deliver the sludge either to the transfer sump or to a rotary vacuum filter for dewatering. At present the sludge which cannot be handled by filtration is pumped to the transfer sump whence it is pumped a distance of over 600 yards to a lagoon by means of two high lift pumps.

Fines Cleaning and Wet Screening Plant

The mineral separation flotation cells incorporated in the Nantgarw plant were designed and manufactured at the Erith works, and the results which have been obtained are stated to be well up to expectations. In a pilot plant in South Wales much of the experimental work necessary to develop the two-process plant was undertaken with the co-operation of the officials of the then Ocean Coal Company, Ltd.

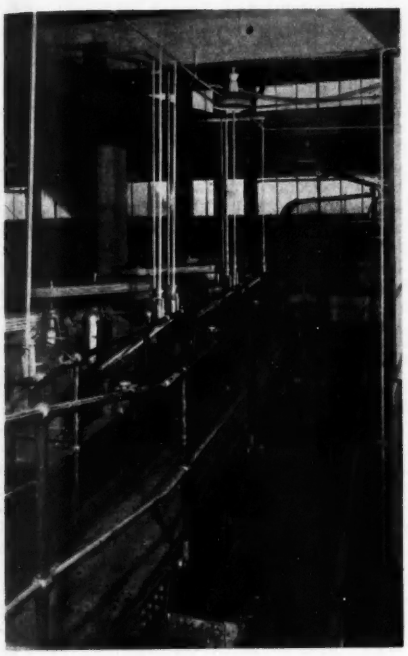
The treatment of coal below ½mm in size had, of course, been a practicable proposition for many years. The purpose of the experiments with the pilot plant, therefore, was to ascertain if it was possible to increase the size range treated by froth flotation up to ⅛in, as the " Chance " process was already capable of treating coal down to that size. At the time that work was proceeding on the pilot plant a series of experiments was carried out in the G.E.C. laboratories at Wembley. It was found that coals which were amenable to froth flotation up to ½mm in size could be successfully treated by this means up to ⅛in in size, and the results obtained closely approached those expected. Another important discovery was the fact that a larger quantity of ⅛in × 0 could be handled by a given cell volume than was the case with ½mm × 0. This has the advantage that, while the quantity of ⅛in × 0 contained in a raw coal is obviously more than that of ½mm × 0, the plant capacity need not be increased *pro rata* to the tonnage of these fractions.

In addition to the question of flotation of material up to ⅛in in size, the practicability of



Base of " Chance " cone showing connection for future middlings column

dewatering it on vacuum filters and of dealing with it in thickeners also had to be considered, apart from the problem of extracting it efficiently from the raw coal feed when the latter had free moisture contents of the order of 10 per cent. Fortunately, the solution to these requirements incurred no undue difficulties. It was found that $\frac{1}{4}$in×0 material could be handled in a conventional thickener, while filtration was possible with a rotary vacuum filter. So far as screening was concerned, it was found that the equipment necessary for the removal of the $\frac{1}{4}$in×0, when the coal was dry, was suitable, provided that additional water was added to assist in washing the fine material through the screen meshes. The weight of water required for froth flotation purposes is approximately ten times that of the coal to be treated, whereas it was found that the $\frac{1}{4}$in×0 coal could be extracted with water-solid ratios of less than this. The equipment used for wet screening is essentially the same as that previously described for dry screening with the



Bank of froth flotation cells

exception that it is necessary to install the "Sherwen" screens at an angle of about 20 deg. instead of 35 deg. Similar efficiencies can be obtained by wet screening methods to those of dry screening so that a two-process plant became a practicable proposition.

Electrical Equipment

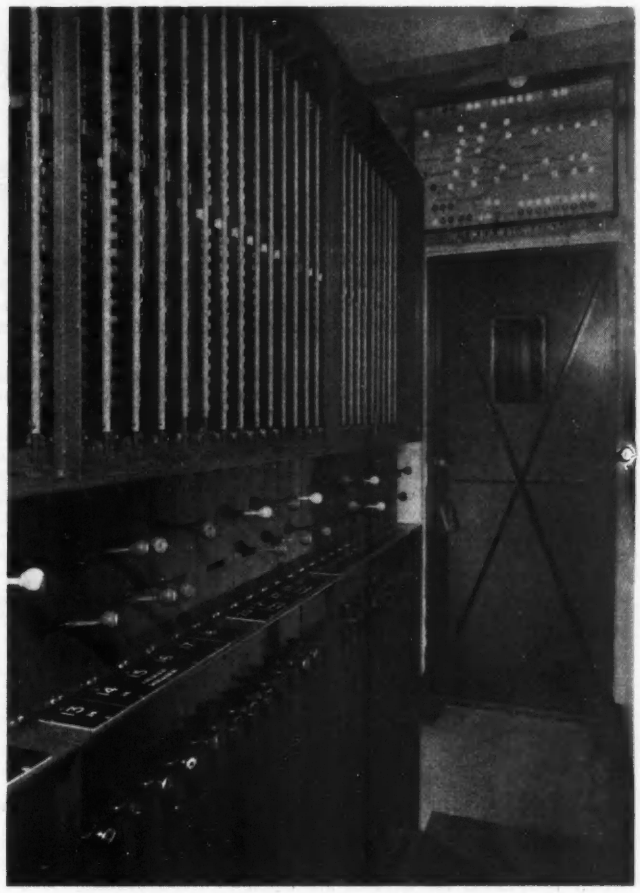
The whole of the driving motors and the contactor control gear for the installation was designed and manufactured at the Witton Works of the G.E.C. Many of the drives are such that there is a high inertia on starting, and in the normal course of events would have necessitated the use of slipring driving motors with the relatively more expensive and complicated control gear. To overcome this difficulty, fluid couplings have been fitted wherever there is a high starting inertia and the smooth starting conditions so obtained reduce the wear and tear on both the mechanical and electrical equipment.

A considerable portion of the plant is sequence interlocked to avoid any complications in the event of a particular conveyor or screen tripping out. It was felt, however, that with certain items sequencing was more of a hindrance than a help to plant operation, particularly in the froth flotation and water clarification sections. All the motor control gear, however, has provision for interlocking so that sequencing may be added in the future if it is found to be necessary due to changing conditions.

In order to avoid the inconvenience of a number of units tripping out in the event of another failing, the plant has been sequenced so that a minimum of other units are tripped out if one fails. This also enables the operators to start up different sections of the plant simultaneously without waiting for a number of other items to be started up first. This is assisted by a comprehensive sequence signalling system, which is arranged so that, when a particular item on one of the group boards is started, it automatically illuminates a lamp on the item next in sequence, if it is on a different group board.

In cases where there are alternative flows for a particular material, the correct sequence is automatically selected by means of a switch attached to the flopper valve of the appropriate conveyor discharge chute. In addition, lights are fitted on the starter for the item next in sequence to the double flow, to show the operator the position of the chute flopper valve.

The contract included the whole of the civil engineering work associated with the coal preparation plant. The site was an extremely difficult one from the civil engineering point of view, as the natural ground was marshy and a stream ran across it from north to south. It was necessary to raise the level of the ground by approximately 20ft in order to obtain suitable falls on the sidings, &c., and the stream had, therefore, to be contained in a culvert. After the culvert had been constructed and the ground filled to the required level, piles of 14in square section and about 55ft long had to be driven to support all important loads. The washery building is of reinforced concrete construction with 4½in thick brick panelled walls, 4in thick reinforced concrete floors and roof. This kind of construction was used to reduce the building maintenance costs on account of the proximity of the coke ovens.



Remote control signalling equipment for Aldersgate

Aldersgate Signalling Installation

In renewing the signalling equipment in the vicinity of Aldersgate, on the Circle Line, London Transport has introduced a new design of remote control equipment. The signalling of this section was formerly controlled from Aldersgate signalbox with electro-mechanical equipment, with mechanical levers for the points, slides for the signals and electrical interlocking. In addition to the main line traffic on the Circle Line, a section of the widened City lines was controlled and there were connections to sidings. The new equipment is remotely controlled from Farringdon signalbox, thus permitting the elimination of the Aldersgate box. In the new installation the lever frame is replaced by an "interlocking machine," controlled by push buttons from the signalbox at Farringdon.

The interlocking machine, which can be seen in the accompanying illustration, is of a simple design with thirty-six vertical shafts, each operating one signal or point function, and provision is made for mechanical interlocking between the shafts. At the base of each shaft two small compressed air cylinders are fitted to supply the rotational movement. Set immediately above the compressed air cylinders is the mechanical locking equipment, and above this an electrical lock provides the back locking and track locking; finally, at the top of the machine, there are sets of contacts for controlling the signal and point circuits.

The Aldersgate interlocking machine operates twenty signals and fourteen sets of points and it is controlled by a small auxiliary push-button panel in the Farringdon signalbox, comprising twenty-three pushes for nineteen routes. The machine, instead of being an adaptation of previous apparatus to suit remote control, is specifically designed for its purpose. Its advantages over the former remotely controlled signal lever frames include economy, simplicity and space saving, combined with full efficiency in performance.

In the development of this equipment a complete change has been made in the design of the mechanical locking. Instead of being a fitter's hand-made job as previously, the present design provides for the mechanical locking to be assembled from a set of standardised components, and only a screwdriver is required for assembling. If an alteration is necessary, it can be carried out in a short space of time and without fitting work.

Following the Aldersgate installation, it has been decided to provide three interlocking machines in connection with resignalling at Camden Town (Northern Line) this year, and the system is likely to be extensively employed elsewhere. The new machine was designed in the signal department of London Transport, the detailed designing having been done by the Westinghouse Signal and Brake Company, Ltd.

Prizes Donated by the Society of British Aircraft Constructors.—The Governors of the College of Aeronautics have announced that the Society of British Aircraft Constructors, Ltd., has donated three prizes to be awarded each year to students specialising in the departments of aircraft design, aircraft propulsion, and aircraft economics and production respectively. The value of each prize is £25, to be taken in the form of books or instruments at the choice of the recipient.

Colorado-Big Thompson Project

BY OUR AMERICAN EDITOR

No. II—(*Continued from page 792, June 3rd*)

For the past fifteen years the Colorado-Big Thompson scheme of the U.S. Bureau of Reclamation has been the major civil engineering work under construction in Northern Colorado. The scheme is now almost completed and, in fact, functioned last summer to save irrigated lands from crop failure due to drought. It gathers waters on the western slope of the Rocky Mountains and diverts them through a 13-mile long tunnel underneath the Continental Divide to the eastern slope, there supplementing the irrigation water supply. The potential of the water is used in several power stations to generate approximately 600 million kWh annually.

Power Generating and Pumping Works

CERTAIN general characteristics are common to all the power installations of the scheme. Each individual turbine or pump employs a unit system, thus ensuring the flexibility of the overall project operation by making each unit independent of all others through its own penstock and transformer or switchgear bank. The following table lists the five power stations within the project.

Power Stations of the Colorado-Big Thompson Project

Power station	Generating units	Installed capacity, kW	Average static head, feet	Hydraulic capacity, cusecs	Penstock length, each, feet	Switchyard capacity, kVA
Green Mountain	2	21,600	203	1,660	906	24,000
Marys Lake	1	8,100	201	550	533	10,000
Estes	3	45,000	557	1,300	4,085	50,000
Pole Hill...	1	33,250	832	550	1,850	40,000
Flatiron	2	63,000	1,115	960	5,550	80,000

All of the turbines used are vertical-shaft, single-runner, Francis machines with a spiral casing embedded in the concrete sub-structure of the power station. With one exception (Green Mountain), all turbines are equipped with mechanically-operated pressure regulators which have the same discharge capacity as the turbine to which they are connected and which act either as synchronous by-passes or as water-saving valves. The pressure regulator valves are connected mechanically to the turbine gate operating mechanisms and are controlled by the governor operating the turbine wicket gates. All turbines have single-pier draught tubes.

The turbine governors are of the oil-pressure, relay-valve, actuator design, with electrically-driven, speed-responsive elements. The governors function to regulate the speed of each unit, to control the gate openings of the turbines and to operate the pressure regulator valves. Using double-acting servo-motors, the governors are capable of operating the turbine gates and pressure regulator relief valves through a complete closing or opening stroke in five seconds, with an oil pressure of 250 lb per square inch. In each installation the generators are vertical-shaft, water-wheel-driven units. The generators are completely enclosed, air cooled by the use of water cooled heat exchangers, and fire-protected by CO_2 equipment. Each generator is equipped with a direct-connected exciter and a voltage regulator. The voltage regulators are rotating amplifier units, except at Green Mountain, where they are the conventional high-speed type.

Each power station is provided with station service equipment, a control room, batteries for emergency operations in case of power failure, sufficient space for dismantling one unit at a time, and for emptying the switchyard transformers.

Green Mountain Dam and Power Station

The Green Mountain dam, with a structural height of 309ft, a volume of 4,300,000 cubic yards and a spillway capacity of 25,000 cusecs, is the major earth and rock fill structure within the Colorado-Big Thompson project. Its design and construction is representative of those also employed in the case of the other earth and rock fill dams of the scheme and will, therefore, be reviewed in greater detail. The dam site was chosen to create a suitable replacement reservoir for the benefit of western slope water users, close to the area where irrigation replacement was necessary. This site was also convenient for the development of power, to fit into the other power developments of the project and the requirements of the utility companies of the State of Colorado.

The Green Mountain reservoir has a capacity of 152,000 acre-feet of water, 52,000 acre-feet of which is replacement capacity for project diversions and 100,000 acre-feet of which is available for power generating purposes. Its irrigation outlet capacity is 1000 cusecs and its power generation outlet capacity is 1500 cusecs. Its spillway capacity is 25,000 cusecs. The reservoir is situated on the Blue River, about 16 miles south-east of Kremmling, Colorado, in a canyon north of the Gore Range of the Rockies. The reservoir extends up to the Blue River for a distance of 7 miles and has an area of 2125 acres. The hills bordering the north-east side of the reservoir are, in general, more abrupt than those on the south-west side and include a high outcropping of rock called Green Mountain, from which the dam takes its name. The area which was submerged by the reservoir consisted of hay and grazing land, with sage-brush and some scattered timber.

Four potential dam sites within a distance of 1¼ miles were studied, and foundation investigations were carried out at the two upstream sites. The topography and geology were quite similar at all of the sites. A concrete gravity dam was considered at one of the sites farthest down the river; but at the upstream sites only earth and rock fill dams were considered. Total costs as well as the unit cost per acre-foot of storage dictated the selection of one of the upstream sites. While the lowest cost per acre-foot of storage was at the adopted site, the controlling consideration in selection was the overburden of gravel at the left abutment of the second-best site. The danger of not obtaining a good cut-off to bedrock on the left abutment excluded this site. Nearly all the area at the dam site finally selected was covered by overburden. On the right abutment, it consisted of soil and slide rock up to 35ft thick. On the left abutment, it consisted of glacial till, gravel and boulders, with a maximum thickness of 65ft. The rock floor was made up of several different types of rocks, the principal members of which were sandstones and shales and porphyritic igneous intrusions. No important faults were found and smaller slip-shears or seams presented no special difficulties. The sandstones were hard and durable. The softer shales, though not suitable as foundation for a masonry dam, were tight and considered to be satisfactory for the construction of an earth dam.

The plan and the sectional elevations of the embankment, as shown on the accompanying drawing, were followed with only minor modifications during the actual construction. From the lowest point in the river gorge the dam extends upward 309ft to the 40ft wide roadway crest, with an average height of 274ft above stream bed. The slopes limiting the zones of the various materials within the body of the embankment were so adjusted as to utilise available materials to the best advantage. The volume of the compacted earth fill and dumped rock fill placed in the dam amounted to a little over 4,316,000 cubic

Fig. 3—The Green Mountain dam, reservoir and power station

Fig. 4—Power station and switchyard at the Green Mountain dam

yards. The upstream zone 2 material was about one-ninth the volume of the earth materials in the dam. The impervious zone 1 material, classified as a screened glacial drift and made up of sand, silt and clay, occupied about five-ninths of the volume. Cobble and rock fill constituted the downstream one-third of the volume of the dam. Construction of a sluiced cobble and rock fill inverted filter, 15ft thick, was considered necessary under the downstream rock fill section of the dam. In case any leakage occurred, this filter was intended to prevent washing of fines, such as clays, silts and sands, from the foundation into the rock fill. Four concrete cut-off walls were placed in the foundation rock of the dam, one of them in the upstream cofferdam area.

The spillway of the dam is situated on the left abutment and consists of a concrete-lined open channel designed for a maximum discharge of 25,000 cusecs. The release of water from the reservoir is controlled by three radial gates, 25ft wide and 22ft high. The outlet channel for the spillway is about 1000ft long and, to obtain better flow conditions, is made up of a series of vertical curves, dropping from elevation 7928 at the spillway crest to elevation 7700 at the discharge end of the channel.

The entrance to the outlet works is situated in the reservoir on the right abutment and consists of a 15ft 5in diameter concrete-lined vertical intake shaft protected by a trashrack tower within which can be installed a 20ft 5in timber cylinder for the emergency unwatering of the intake shaft and tunnel. The intake shaft is connected by a 90 deg. bend with a concrete-lined 18ft diameter tunnel driven through rock. The tunnel leads to a gate chamber situated in rock and connected to the top of the dam through a 20ft diameter vertical shaft. The gate chamber contains two 102in ring-seal slide gates which are for emergency control of the flow of water into the steel penstocks leading to the power station and the irrigation release pipes. Downstream from the gate chamber the tunnel is horseshoe-shaped with maximum dimensions of 23ft high and 16ft wide. This horseshoe tunnel contains two 102in diameter penstocks, each of which is reduced to 84in in diameter for connection to the turbines. Two 50in outlet pipes branch from the 102in pipes near the power station and are connected to 42in needle valves which control the irrigation releases.

A reinforced concrete power station, which is shown in the illustrations opposite, is situated on the east bank or right side of the Blue River, immediately below the dam. The building is 67ft by 97ft and houses two 15,000 h.p. turbines and the two 42in outlet valves. The plant is operated under a variable head of water in the reservoir of from 120ft to 255ft. Maximum horsepower capacity is reached under a head of slightly over 200ft, and best efficiency is obtained while operating under an effective head of between 200ft and 220ft. The generating units are each equipped with a generator rated at 12MVA and 0·9 power factor when driven at 257 r.p.m. by a turbine with a rated capacity of 15,000 h.p. at a 185ft head.

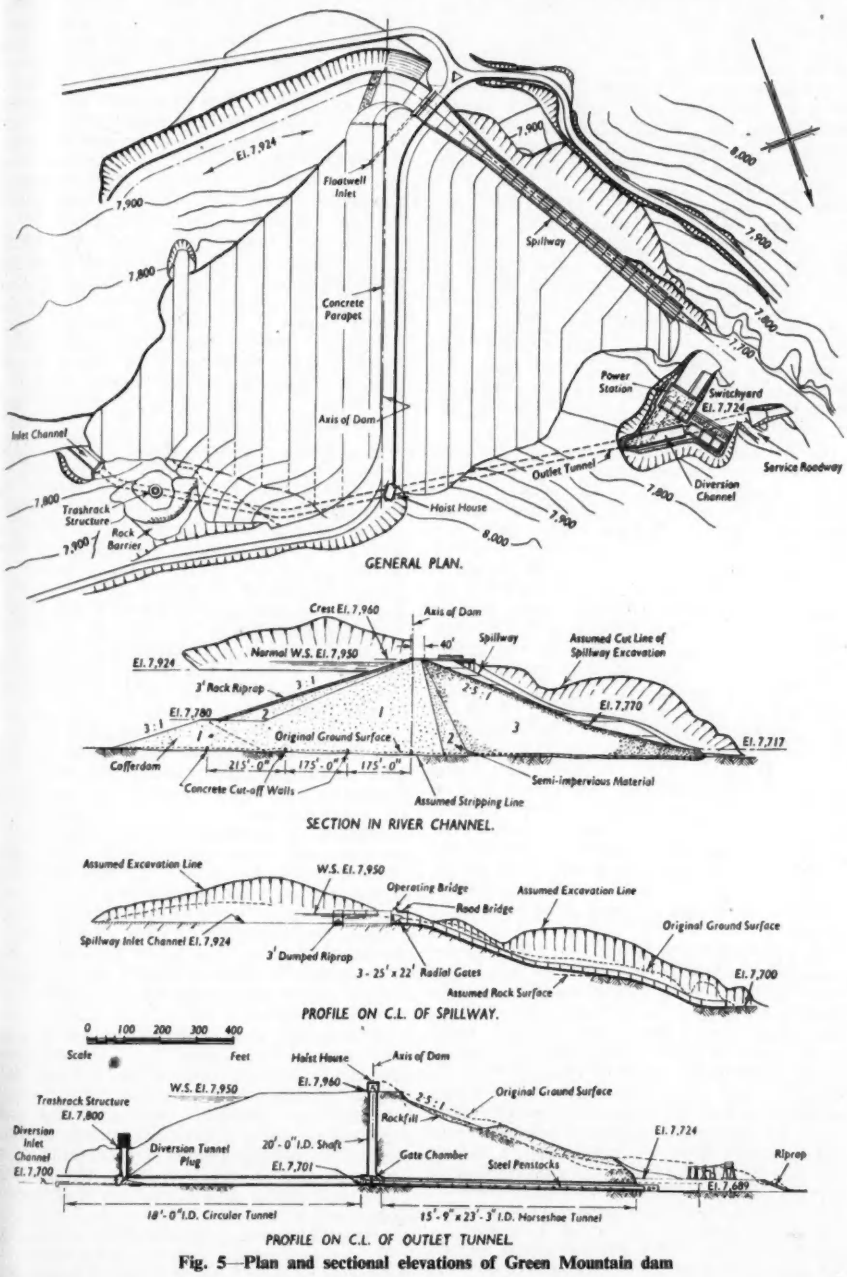


Fig. 5—Plan and sectional elevations of Green Mountain dam

Construction of Dam and Power Station

In designing the Green Mountain dam it was necessary to provide for some means of diverting the Blue River, at least temporarily, from the dam site to permit excavation and construction on the lowest parts of the foundation. This problem was handled by using the outlet tunnel to take care of river flows. During construction, the outlet tunnel was connected with a temporary tunnel upstream from the intake structure and with an open channel downstream from the end of the outlet tunnel. Shortly before completion of the dam, the intake of the temporary upstream diversion tunnel was bulkheaded to permit the construction of a concrete plug at its lower end, thus connecting the outlet tunnel to the permanent intake shaft. During the same period, the diversion channel below the outlet tunnel portal was removed, and the ring-seal gates were installed in the gate chamber. With this work completed, the flow of the river was under control.

In the excavation of the outlet tunnel, work was started at the upper or inlet end of the tunnel because of the necessity of first removing about 70,000 cubic yards of common overburden excavation and about the same amount of rock. The rock through which the tunnel was excavated consisted of formations of sandstone and shale, and porphyry intrusions. After excavation, rock in the tunnel required the support of 6in I-beam steel ribs, weighing 12½ lb per foot and spaced from 16in to 72in apart. The type of drill round used was a modified V-cut, which was changed to suit rock conditions. From forty-four to fifty-two holes were drilled per round in the tunnel upstream from the gate chamber, and as many as seventy-six holes per round were necessary in the penstock tunnel leading to the power station. Drilling was usually done in 8ft rounds. Muck was loaded into diesel-powered trucks by an electrically operated slusher scraper mounted on a narrow-gauge track. Mining methods were used in sinking the 20ft diameter gate chamber shaft for a distance of 150ft. In the first instance an 8ft by 8ft square pilot shaft was sunk to intersect the tunnel at the gate chamber. The pilot shaft was then enlarged from the top down, the muck being drawn off as necessary from the bottom and removed from the tunnel. Lining of the gate chamber shaft with 18in to 30in of concrete, depending on the soundness of the rock encountered, followed the excavation down in 10ft lifts. The circular section of the tunnel has a minimum thickness of concrete of 18in and the horseshoe section has a minimum thickness of 24in, with the amount of concrete per linear foot of tunnel ranging between 4½ to 6½ cubic yards.

The rock outside the tunnel and shaft linings was consolidated and strengthened by injecting, under pressure, cement grout into holes drilled into the rock through pipes set in the concrete. Relatively little cement grout was forced into the undisturbed shale rock; however, where grout holes penetrated porphyry and sandstone in the gate chamber and inlet shafts, it was possible to pump large quantities. Pressures used in the tunnel and shafts varied from 50 to 200 lb per square inch. Several large crevices under the trackrash structure were grouted initially with a sand-cement grout and later re-grouted with neat cement grout. When the necessary work in the outlet tunnel was completed, the river was diverted through the tunnel by means of a temporary cofferdam across the river upstream. The cofferdam consisted of steel sheet piles interlocked with one another and driven to foundation rock under the river. The sheet piles were supported on each side by soil, gravel, and other waste overburden materials

removed from the dam site prior to actual construction of the dam.

At the time of its commencement, the Green Mountain dam was the highest and largest earth fill dam ever undertaken by the Bureau of Reclamation. The stripping of unsuitable material from the dam site involved maximum vertical depths of 78ft on the left abutment, 92ft on the right abutment, and 45ft in the river channel. The average depth of excavation through the river channel was about 10ft. All usable materials were stripped separately and either hauled upstream from the dam site and stored in stock piles for later application or, where feasible, placed immediately in the dam. The unsuitable materials, such as weathered and badly broken shales, sandstones, and decomposed shale, were wasted at the upstream end of the dam or along the river bank. A "plunge basin," as it is geologically known, was discovered while excavating for the dam foundation. This formation was encountered on the foundation 37ft below the surface of the earth. Some 30ft wide by 100 ft long, the basin had been carved out of a hard porphyry rock and then filled with about 2000 cubic yards of river sediments consisting mostly of gravel. In appearance the plunge basin greatly resembled a dry waterfall. This geological oddity being directly beneath the dam, it was necessary to fill it with selected materials and compact them to the same density as required for the rolled-earth dam sections. Filling the plunge basin increased the maximum height of the dam from 272ft to 309ft.

Four reinforced concrete cut-off walls discourage seepage beneath the dam embankment at its contact with the rock foundation. Prior to concreting the cut-off wall footings, 2in diameter pipes were supported vertically in the excavated trenches at spacings of not more than 10ft. After the concrete in the footing trenches had set, holes were drilled into the foundation rock through the grout pipes to depths as great as 150ft. Mixtures of neat cement and water were forced into these holes at pressures ranging from 30 lb per square inch in the shale to 100 lb per square inch in the porphyry. Supplemental grouting of the foundation rock benches on the left abutment between the cut-off walls was performed to reduce the seepage water and to localise excess flows so they could be more effctively handled in sumps and drains. Earth materials available from the abutment stripping and from borrow pits were suitable for the earth fill section of the dam but contained a large percentage of glacial cobbles and boulders. Getting the material from borrow pits to the dam was not only a problem of transport down steep canyon slopes, but also one of separation into two main classes of fill—rock for pervious fill, and fines for impervious rolled embankment. The solution was to combine transport and processing with a downhill haul from borrow pit to the separation plant, gravity flow of materials through the plant, and more downhill haul of the separated materials to the fill. After some experimenting, the contractor placed the separation plant high on the canyon wall, low enough for the downhill haul from the pit and also high enough to transport processed materials to final position with downhill hauls.

At the pit, material was loaded into bottom-dump tractor trucks by shovels. The trucks reached the top of the plant via a circular trestle and slowed down just long enough to straddle and dump into a divided receiving hopper before returning to the pit. Material under 3in was diverted to a receiving hopper for the fines, while the rejects and larger rock continued their flow down into the end of the chute. The hopper for fines was fitted with slide gates for discharge into bottom-dump tractor trailers travelling on a winding road of fairly easy grades leading to the upstream and centre parts of the dam, where the fines for the impervious core of the dam were deposited. The rock chute contained endless slack chains with 3in links. As the chains were slowly rotated, the underside of the loops, i.e. the side next to the rock in the chute, moved downward, permitting the rock to dribble out of the end of the chute into waiting end-dump trucks. By stopping the movement of the chains, the flow of rock was stopped. Good haul roads were maintained down the sides of the canyon to the downstream section of the dam for these trucks. The bottom-dump tractor trailers deposited the impervious material in windrows to be spread by bulldozers, after which the material was rolled and compacted with sheepsfoot rollers.

Special attention was paid to the contact between the impervious fill materials and the foundation rock. The rock faces were cleaned and the material thoroughly tamped against them. One of the interesting construction aspects was the use of emulsified asphalt for the treatment of the shale foundation which occupied much of the dam site and which disintegrated when exposed to air for a prolonged period. The procedure was to blow off all the loose material down to a clean, tight surface and then spray the solid shale with emulsified asphalt. The total amount of seepage water that flowed into the dam foundation area, power station foundation, and spillway was comparatively small, but it entered at many places. Most of this water was removed by pumping or through gravity pipelines. A number of small seeps along the dam abutments in the canyon walls were taken care of by bailing until sufficient compacted earth was placed to smother them completely. In a few places, a pump sump or well was made from a bottomless oil drum with perforated sides, or from a large piece of pipe set over or close to the seep, around which was placed clean gravel. Grout pipes were placed at the bottom of each sump and, after the sumps had served their purpose, the pipes were capped and filled with grout when 30ft of earth fill had been placed over them.

In the construction of the concrete overflow spillway section, to prevent any possible damage from hydrostatic uplift pressures under the spillway, tile drains and free-draining gravel blankets were constructed, and steel anchor bars were embedded in the foundation rock prior to placing the spillway concrete. An effort was made to force grout into a line of holes drilled below the bottom of the spillway cut-off trench, but the rock was very tight and little grout was injected. The first concrete was placed in the cut-off trench across the lower end of the spillway channel. The steep grade, severe climatic conditions, and lack of skilled labour made placing of the floor sections a tedious job. The removal of the earth material down to bedrock over the area to be occupied by the power station was carried on simultaneously with similar excavation for the outlet channel. The necessary rock excavation for the switchyard was done at the same time by the same methods as used on the power station foundation. The excavation for the power station proper consisted of the removal of the porphyry rock to a depth of 68ft.

Shortly before the power plant commenced operations, it was determined that, by lowering the river bed over a distance of approximately 1600ft downstream from the power station, the annual power output of the plant would be increased by about 3,500,000kWh. Accordingly 27,000 cubic yards of material were excavated from the river bottom. The Green Mountain reservoir now satisfactorily stores water for release to water users downstream on the Colorado River. Such releases, at a rate to offset the effect of diversion of water from the Granby reservoir to the eastern slope, require a draw-down of the Green Mountain reservoir of approximately 135ft each year in advance of the flood season. More than 80,000,000kWh of electrical energy are generated yearly at the dam and transmitted to utility companies throughout the State of Colorado.

Power Demonstration Reactor Programme of the A.E.C.

THE U.S. Atomic Energy Commission has announced that four proposals have been made by public and private organisations under the Power Demonstration Reactor Programme. The four proposed power plants would have a total of 455MW electrical capacity. Taking the proposals as a group, the estimated capital cost of the four plants would be about 150 million dollars, of which 80 to 90 per cent would be borne by the proposers. The proposals received are :—

(1) A boiling water reactor plant of 180MW capacity, to be completed in 1960. This plant is proposed by the Nuclear Power Group, composed of American Gas and Electric Service Corporation, New York ; Bechtel Corporation, San Francisco ; Commonwealth Edison Company, Chicago ; Pacific Gas and Electric Company, San Francisco ; and Union Electric Company, St. Louis.

(2) A light water moderated and cooled reactor plant of 100MW capacity, to be completed in late 1957 ; proposed by the Yankee Atomic Electric Company, of Boston, members of which are : New England Power Company, Connecticut Light and Power Company, Boston Edison Company, Central Maine Power Company, Hartford Electric Light Company, Connecticut Power Company, Western Massachusetts Electric Company, Public Service Company of New Hampshire, Montaup Electric Company, New Bedford Gas and Edison Light Company, Cambridge Electric Light Company, and Central Vermont Public Service Corporation.

(3) A fast breeder reactor plant with 100MW to be completed in late 1958, proposed by Central Hudson Gas and Electric Corporation, Cincinnati Gas and Electric Corporation, Consumers Power Company, Delaware Power and Light Company, Detroit Edison Company, Long Island Lighting Company, Philadelphia Electric Company, Rochester Gas and Electric Company, Rochester Gas and Electric Corporation, and Toledo Edison Company.

(4) A sodium graphite reactor plant of 75MW capacity, to be completed in 1959, proposed by the Consumers Public Power District of Columbus, Nebraska. In addition to the power reactor schemes contemplated in the proposals under the Power Demonstration Reactor Programme, the Consolidated Edison Company, of New York, has applied to the A.E.C. for a licence to build and operate entirely with private capital a nuclear power plant with a capacity of 250MW, which the company estimates will cost about 55,000,000 dollars. The reactor for this plant would be light water cooled and moderated, and it would take about five years to build.

The Nuclear Power Group proposal asks that the Federal Government assume public liability and property damage in excess of 500,000 dollars, unless insurance is available to the group at a reasonable cost. The Yankee proposal is contingent on adequate insurance being available at a cost not substantially greater than 150,000 dollars a year. In the third proposal the utilities group stipulates that there must be reasonable assurance that adequate insurance will be obtainable. The Consumers Public Power District proposal asks that the Federal Government provide insurance coverage beyond those amounts which insurance companies will assume at reasonable cost.

Under the Power Demonstration Reactor Programme the Commission announced in January that it would consider giving the following kinds of co-operation and assistance : (*a*) waiving the established Commission charges for loan of source and special nuclear materials up to an agreed amount for a period of up to seven years from July 1, 1955. However, the licensees will be required to pay for materials consumed in the demonstration project and for services performed for them by the A.E.C., such as the recovery of materials from spent fuel elements ; (*b*) performing in A.E.C. laboratories without charge to the licensees certain mutually agreed research and development work ; and (*c*) entering into research and development contracts for the technical and economic information resulting from development, construction and operation of power demonstration reactors by the contractors. The amounts to be paid by the A.E.C. under the contracts will be fixed in advance and may be used for development, fabrication and experimental operation. Information derived from operations under the contracts will be made available by the A.E.C. to the maximum extent practicable to the entire technical public working on reactor development, with resultant benefit to the progress of the entire nuclear power programme.

Industrial and Labour Notes

The Railway Strike

Many sectors of industry this week have felt the effects of the strike of locomotive men on British Railways, which began on May 28th. On Monday there was a meeting of the emergency committee of the National Production Advisory Council on Industry, under the chairmanship of the Minister of Fuel and Power, to consider the industrial position. At that meeting it was reported that shortage of fuel had not so far led to serious difficulties, and that, generally, in the first week of the railway strike, industry had been able to maintain a high level of production and employment. It was stated, however, that some industries were already suffering severely from the congestion of finished products owing to the dock strike ; in many cases the railway strike was adding to that congestion and was also causing a rapidly increasing shortage of raw materials, which would inevitably lead before long to short time and serious unemployment.

As we go to press there is some indication that efforts to end the strike may be successful. As explained in a leading article on page 814 of this issue, the strike was called by the Associated Society of Locomotive Engineers and Firemen after negotiations with the British Transport Commission on wage differentials had broken down. Last Sunday evening, in a broadcast talk, the Prime Minister, Sir Anthony Eden, reported on the steps that had been taken to maintain essential supplies and services, and again stated that the British Transport Commission was agreeable to the appointment, by the Minister of Labour, of a conciliation board to assist in resolving the dispute. On Monday the chairman of the British Transport Commission, Sir Brian Robertson, addressed a letter to Mr. Baty, the general secretary of the Associated Society of Locomotive Engineers and Firemen, asking the society, in its own interests and those of the country, to consider the immediate cancellation of the strike and the resumption of negotiations. The letter added that the Commission would then be ready to consider with A.S.L.E.F., and with the National Union of Railwaymen, "any proposal for giving reasonable additional rewards for special responsibility or skill where these were not given already."

On Monday afternoon, the general council of the Trades Union Congress held a special meeting to consider the strike. At the end of it, the T.U.C. stated that it had formulated a five-point plan aimed at bringing about a settlement. The T.U.C.'s principal suggestions were : that the question of differentials should be referred for future joint discussions between the three railway unions ; that the N.U.R. should agree that the British Transport Commission could start discussions with A.S.L.E.F. on the settlement of the dispute on footplate men's pay, on the understanding that it (the N.U.R.) was consulted before any settlement ; that the A.S.L.E.F. should agree to meet the British Transport Commission with a view to establishing absolute minimum increases to settle the dispute, bearing in mind the proposed discussions on differentials, and should agree to consider a return to work as soon as a settlement emerged. The final points in the T.U.C.'s plan were that its general council should keep the matter under review, and that, if agreement could be reached on the basis suggested, the general council would approach the Prime Minister, pressing him to agree that negotiations should begin while the strike was still on. The proposals were considered by the executives of the A.S.L.E.F. and the N.U.R., and on Tuesday evening A.S.L.E.F. stated that it accepted the provisions of the T.U.C. "peace formula." At the same time, the N.U.R. issued a statement which, it said, should not be regarded as acceptance or rejection of the proposals. The N.U.R. said that it would have no objection to a preliminary meeting between the A.S.L.E.F. and the British Transport Commission, but claimed that it must be present at any subsequent negotiations.

During the two weeks of the strike it has not been possible, of course, for British Railways to operate more than a small proportion of its normal services, as only about 25 per cent of its locomotive staff are members of the National Union of Railwaymen. But the number of trains run, and freight trains in particular, has been steadily increased. The British Transport Commission stated, for example, that between 6 a.m. and 2 p.m. last Tuesday 2213 passenger and 1413 freight trains were operated.

Shipbuilding Industry's Outlook

Speaking at the annual meeting of Cammell Laird and Co., Ltd., on Tuesday, the chairman, Mr. J. C. Mather, said that if the shipbuilding industry was to improve its position and maintain full employment, it must be critical of its own shortcomings and do its utmost to put them right. The industry, he continued, had a forty-four-hour working week, and whilst many employees observed that condition conscientiously there were many who did not. A high percentage of absenteeism was also experienced, much of which was not justifiable. Furthermore, Mr. Mather observed, production was affected by inter-union disputes over the demarcation of jobs, a matter which, he considered, should be tackled by the trade unions at a national level. Then, bans on overtime were prevalent in the industry, and these had a crippling effect on production. If these problems could be overcome, Mr. Mather emphasised, the shipbuilding industry would be in a much stronger position to attract the additional business necessary to ensure the prosperity of all engaged in it.

Coal Production

The National Coal Board and the Ministry of Fuel and Power have stated that, despite transport difficulties created by the railway strike, the movement of coal from the pits last week was satisfactory. The total output of coal last week, which included the Whitsun holiday, was 3,316,100 tons, made up of 3,136,400 tons from the deep mines and 179,700 tons from opencast workings. The deep-mined output was about 10,000 tons less than in Whitsun week last year. In the first twenty-two weeks of this year, up to last Saturday, coal production amounted to 95,700,700 tons, compared with 99,366,100 tons in the corresponding period of last year. The loss of deep-mined output through disputes in the first twenty-two weeks of this year has been estimated at 1,891,300 tons, against 671,600 tons in the comparable period of last year. In the first twenty-one weeks of this year 4,639,200 tons of coal were imported.

Copper and Zinc

According to statistics which have been compiled by the British Bureau of Non-Ferrous Metal Statistics, world smelter production of copper last year (excluding secondary production) amounted to 2,706,400 long tons. This was 9000 tons less than in the preceding year. In the U.S.A., copper output last year declined by 91,000 tons to 844,553 tons, but there were increases in many other countries, notably in Canada and the Belgian Congo.

The Bureau has also stated that last year's world production of slab zinc totalled 2,368,000 tons, which was 41,100 tons more than in 1953. The total included an estimated production of 323,000 tons in the U.S.S.R., Poland and other Soviet controlled territories. Zinc production in the U.S.A. declined by about 90,000 tons last year, and in Canada by over 27,000 tons. But, the Bureau says, these decreases were more than offset by increased output in most other zinc producing countries, notably in Belgium, France, Germany, Japan and in the Belgian Congo, where production did not start until 1953.

Production of Iron Castings

The Council of Ironfoundry Associations has stated that in the first quarter of this year iron foundries in the United Kingdom produced 1,018,000 tons of castings. This was nearly 5½ per cent higher than the output in the first quarter of last year. The Council says that the greater output was most marked in automobile castings, production of which is now about 25 per cent greater than a year ago. The output of iron castings for the engineering industry generally continues to rise. The only substantial decline, the Association adds, has been in railway castings output of which in the first quarter of this year was 12 per cent lower than in the corresponding quarter of last year.

About raw materials for the ironfounding industry, the Council says that 650,000 tons of pig iron and 817,000 tons of scrap were used in the first quarter, which represents increases of 4·6 per cent and 7·8 per cent, respectively, over the comparable period of last year. Stocks of pig iron at the foundries were well maintained during the first quarter, with the exception of hematite. As to employment in the ironfounding industry, the Council's statistics show that, following a prolonged rise, the labour force levelled off during February and March. On April 2nd, the industry's labour force totalled 144,740.

Institute of Cost and Works Accountants

Last week, the Institute of Cost and Works Accountants held its annual conference in London. At the opening session on Friday morning, the retiring president, Mr. W. E. Harrison, delivered an address in the course of which he said that the past year had been a good one for British industry. Production and productivity had both increased, salaries and wages had increased sharply, and profits had improved to an almost similar extent. Government expenditure and taxation had been reduced, Mr. Harrison added, and there had been considerable relaxation of controls and restrictions. He went on to comment that these improvements had occurred in spite of a worsening in the terms of trade, and increased competition in the export markets, together with a fall in the output of coal, and more recently, loss of production through ill-advised and unnecessary strikes.

The reason for the increase in prosperity, Mr. Harrison continued, was to be found in the growing confidence and enterprise in industry and in a determination to succeed, which was probably the greatest pre-requisite to success. It was not his intention, Mr. Harrison observed, to give to the government of the day any advice regarding the methods and extent of taxation. Ultimately, he said, all taxation must be raised by the efforts of the workers at all levels in industry and commerce, and unless expenditure was reduced changes in taxation methods merely removed the burden from one place to another. The objectives should surely be, therefore, to reduce Government expenditure wherever possible, and to increase industrial efficiency and production so that the burden was more readily borne. The rate at which we progressed, Mr. Harrison suggested, rested far more with the people—the workers, foremen and managers at all levels—than with the Government. The achievement of success, Mr. Harrison said, rested largely in the hands of industry. There had been considerable expansion of industry in recent years, and that must be continued, with the emphasis upon improvement possibly more than extension. Industry must continue to install up-to-date plant and to use methods which were intended to reduce the costs of production. At the same time, Mr. Harrison added, the workers must co-operate in using these appliances to the best of their ability, and there must be a genuine desire on the part of both management and labour to remove all restrictions on output.

Following the presidential address, Mr. E. F. Brown introduced a discussion on educational influences in the work and training of cost accountants. On Friday afternoon, there was a discussion on "Work Study and our Standard of Living," which was opened by Mr. R. M. Currie, M.I.C.E. At the annual general meeting of the Institute, which was held on Saturday morning, Mr. George Nicholson was installed as president for the coming year and Mr. Ian T. Morrow and Mr. H. J. Furness were elected vice-presidents.

Personal and Business

Appointments

THE DE HAVILLAND ENGINE COMPANY, Ltd., states that Dr. E. S. Moult, M.I.Mech.E., chief engineer, has been appointed a director.

MR. K. J. CLARKE, A.M.I.E.E., has been appointed assistant manager of the Sheffield office of the British Thomson-Houston Company, Ltd.

SIR WILFRID AYRE has been appointed chairman of the research board of the British Shipbuilding Research Association, in succession to the late Sir Maurice Denny, Bt.

THE PENINSULAR AND ORIENTAL STEAM NAVIGATION COMPANY announces that Captain R. E. Cowell, R.D., A.D.C., R.N.R., has been appointed marine superintendent in succession to the late Captain A. Rodger.

FOLLAND AIRCRAFT, Ltd., Hamble, Southampton, announces the appointment of Mr. F. J. W. Wingfield Digby, F.R.Ae.S., as an assistant chief designer. He was formerly chief designer to Westland Aircraft Company, Ltd.

MR. ROBERT Q. WILSON has been appointed United Kingdom representative of the Battelle Memorial Institute. Mr. Wilson has charge of the London office of Battelle Institute, Ltd., which was opened recently at 46, Bryanston Street, W.1.

THE CENTRAL ELECTRICITY AUTHORITY has appointed Mr. Gerald B. Jackson to be power circuit engineer in the chief engineer's department at headquarters. For the last four years he has been in charge of transmission construction work in the Yorkshire division.

DR. J. H. ARGYRIS has been appointed to the chair of aeronautical structures at the Imperial College of Science and Technology, University of London. Dr. G. D. Hobson has been appointed university reader in oil technology at the Imperial College of Science and Technology.

REAR ADMIRAL J. G. C. GIVEN, M.I.Mech.E., has been appointed to the board of Parsons Marine Turbine Company, Ltd., Wallsend-on-Tyne. He is to succeed Mr. Andrew Hopper as managing director at the end of the year, when Mr. Hopper retires after fifty-four years in the company's service.

Business Announcements

GEORGE KENT, Ltd., Luton, states that it has begun work on a new factory at Hitchin, Herts, for the manufacture of steering gears.

STEEL WOOL FACTORY (LONDON), Ltd., Silverdale Road, Hayes, Middlesex, states that it is now producing "Steewo" steel wool.

SHEEPBRIDGE EQUIPMENT, Ltd., has opened a new fabricating and assembly shop, with an area of over 11,000 square feet, at its works at Sheepbridge, Chesterfield.

THE B.S.A. COMPANY, Ltd., has announced the retirement of Mr. J. A. T. Dickinson, works director of the Small Heath group. He joined the staff of the group in 1914.

BEN THORNTON AND PARTNERS, Ltd., 39, Victoria Street, London, S.W.1, has been formed as a company of engineers' contractors and agents. Mr. B. Thornton is the managing director.

ALBERT MANN'S ENGINEERING COMPANY, Ltd., Basildon Industrial Estate, Essex, has made an agreement for the manufacture in this country of the American designed "Stanat" two-high/four-high combination rolling mills.

SIR HUGH MOLONY, Bt., M.I.C.E., has relinquished his appointment on the engineering staff of the Ministry of Housing and Local Government to take up private consulting work. His address is 40, King William Street, London, E.C.4.

LEONARD SMITH (ENGINEERS), Ltd., is the name of a company established by Mr. E. L. Smith for the design and fabrication of plant for the chemical, brewery, foodstuffs, and dairy industries. Its address is Abford House, Wilton Road, London, S.W.1 (telephone, Victoria 2793).

MARTIN, BLACK (WIRE ROPES), Ltd., announces the opening of new offices and stores for the Midland and N.W. areas at 4, Low Pavement, Nottingham (telephone, Nottingham 47293), 640, Woodborough Road, Mapperley, Nottingham (telephone, Nottingham 64397); Century Building, North John Street, Liverpool (telephone, Central 0924); and 99A, Webster Road, Liverpool (telephone, Sefton Park 6669).

VICKERS-ARMSTRONGS, Ltd., has announced some details of the three subsidiaries which have been formed following reorganisation of the business. Vickers-Armstrongs (Aircraft), Ltd., is responsible for the aircraft business carried on at the Weybridge, Supermarine and other works. Major-General C. A. L. Dunphie is the chairman, and Mr. G. R. Edwards managing director. Vickers-Armstrongs (Engineers), Ltd., has responsibility for the engineering business carried on at Crayford, Barrow, Elswick, Scotswood and other works. Major-General Dunphie is the chairman, Mr. P. H. Muirhead managing director, and Mr. F. P. Laurens deputy managing director. Vickers-Armstrongs (Shipbuilders), Ltd., operates the shipbuilding business at Barrow and the naval yard. Major-General Dunphie is chairman and Mr. G. H. Houlden managing director.

Contracts

FOSTER WHEELER, Ltd., has received a contract from the Iraq Government for the design, supply and construction of a complete lubricating oil refinery in Iraq.

SPENCER (MELKSHAM), Ltd., Melksham, Wilts, has received an order from the British Transport Commission for four automatic travelling pneumatic grain elevators for the Port of Hull.

ENFIELD CABLES, Ltd., has received a contract from the South of Scotland Electricity Board to the value of approximately £130,000, for the supply and installation of cables between Dalmarnock 132kV grid substation and Charlotte Street substation, Glasgow. The installation is part of a reinforcement scheme and comprises two 132kV pipeline compression cable circuits, each suitable for a continuous rating of 136mVA, together with associated auxiliary cables for an approximate route length of 3600 yards.

SIR WILLIAM ARROL AND CO., Ltd., Glasgow, has received a contract to the value of £450,000 for the complete construction of embankment approach roads, piled abutments and river piers and the steel superstructure of a new highway bridge over the River Euphrates at Samawa, about 175 miles south of Baghdad. The overall length spanning the river of 527ft comprises a central span of 261ft between the river piers which carry the main towers, and two side spans, each of 133ft, from pier to abutment. The work is to be carried out to the order of the Iraq Development Board, and the consulting engineers are Maunsell, Posford and Pavry, of Westminster, S.W.1.

Miscellanea

FUEL OIL PIPELINE.—A 6in diameter pipeline with a capacity of 20,000 tons per year, is to be constructed from Kwinana Refinery, Australia, of the British Petroleum Company, Ltd., to supply fuel oil to the nearby steel rolling mill of the Broken Hill Proprietary, Ltd.

DAMP COATING MATERIAL.—We are informed that a new damp coating material incorporating non-toxic, highly reflective and moisture-resistant aluminium pigments is being manufactured by Xzit (G.B.), Ltd. This material is said to be suitable for water tanks and can be applied by spray or brush.

INTERNATIONAL MANAGEMENT MEDAL.—The Council for International Progress in Management (U.S.A.), has awarded the Wallace Clark international management medal to Lieut.-Colonel L. F. Urwick. The award is made for a "distinguished contribution to scientific management in the international field."

PRESSURE FEED OIL CANS.—In the article describing pressure feed oil cans, which appeared in our issue of May 27th, it was inadvertently stated that the cans were distributed in this country by Lida (London), Ltd. They are actually being distributed by an associated company, Sir Thomas Edelston and Partners, Ltd., 28/30, Sussex Place, London, W.2.

RUTHERFORD SCHOLARSHIP.—The Royal Society states that, under the terms of the scheme to commemorate the late Lord Rutherford of Nelson, it has appointed Mr. N. W. Tanner, a graduate of the University of Melbourne, as a Rutherford scholar for three years from October 1st next, to carry out research in nuclear physics at the Cavendish Laboratory, Cambridge.

AIR FILTER AND REDUCING VALVE FOR PAINT SPRAYING.—To ensure a supply of clean air for spray painting the design of the air filter and reducing valves made by Alfred Bullows and Sons, Ltd., Long Street, Walsall, Staffs, has been improved. The main filtering medium now consists of a stack of phenolic resin mouldings, which provide a non-clogging and self-cleaning medium. The air passages impart a series of controlled changes of direction and velocity, so that, with negligible resistance to flow, all condensed particles of water are thrown out of the air stream and returned to the sump for discharge to atmosphere.

MOBILE OIL FIELD SPRAYER.—The Shell Petroleum Company Ltd., has shipped to the Seria Oilfield (British Borneo) a mobile spraying plant designed by E. Allman and Co., Ltd., and built on to a 5-ton Commer chassis. The unit, which will use oil-based sprays to destroy vegetation encroaching on pipelines, has a 45ft aluminium telescopic boom fitted with wide angle jets having a spraying width of 72ft. The boom has a hinged joint at the lower end of the steel supporting tower which rotates on a roller bearing. In addition there are two centrally fed hose reels each carrying 200ft of high pressure solvent rubber hose fitted nozzles giving a spraying width of 24ft.

FAST NAVAL PATROL BOATS.—Her Majesty's fast patrol boat, "Dark Aggressor," the first of a new class powered with Napier "Deltic" diesel engines, has been accepted by the Navy. The boat, which was built by Saunders Roe (Anglesey), Ltd., is of hard chine form, has an extreme length of 71ft 4in by 19ft beam, with a maximum draught of 6ft 1in and a displacement of 64 tons. Aluminium alloy has been used for frames and deck and the hull is planked with two diagonal skins of mahogany. As a gunboat the armament will consist of a 4·5in gun and a single Bofors gun, while in the role of a torpedo boat four single above-water torpedo tubes will be carried.

TRAFFIC SURVEY BETWEEN LONDON AND MIDLANDS.—We are informed that the Road Research Laboratory of D.S.I.R. will be conducting an investigation into traffic movements between the London area and the Midlands during June and July. The object of the work is to study the origins and destinations of traffic using the existing roads. These inquiries are being made in connection with the new road plans. Traffic census points, staffed by local authorities, are being set up at twenty-one sites on main roads in Hertfordshire, Bedfordshire, Buckinghamshire, Northamptonshire, Warwickshire, and Oxfordshire. Some vehicles will be stopped and those drivers who are willing to do so will be invited to provide details of the journeys they are making.

PREVENTION OF ACCIDENTS ON FARMS.—At the request of the council of the Institution of British Agricultural Engineers, the East Anglian centre of the Institution is investigating the possibility of preparing a safety code or codes for employers and machinery operators, and of making recommendations to machinery designers and manufacturers regarding alterations in general design or the provision of additional safety guards where it is felt that these would help to reduce the number of accidents by eliminating dangerous practices or danger spots in particular machines. This is one of a number of activities now being undertaken by the five local centres of the Institution, all designed to be of assistance to the agricultural engineering and agricultural industries.

MR. HAMISH FERGUSON.—It is with regret that we record the death of Mr. Hamish Ferguson, which occurred on May 28th, in hospital at the Hague, Holland, while he was attending the International Internal Combustion Engine Congress. Mr. Ferguson, who was born in 1904, received his early training with the English Electric Company, Ltd., and was later a member of a firm of consultants. In 1944 he became secretary of the Diesel Engine Users' Association, a post which he relinquished in March, 1954, following a long illness. He returned to private consulting work, and founded a company, Diesel Technical Services, to cater for the requirements of potential users of diesel engines and gas turbines, and also continued his work as London correspondent to the American technical journal *Diesel Progress*.

HEAT FLOW IN WELDS.—A conference on heat flow problems, convened by the Institute of Welding, was held on May 16th and 17th, and attended by about twenty investigators drawn from industry, the universities and research associations. At the first two meetings, held under the chairmanship of Professor O. A. Saunders of Imperial College, a general exchange of information and ideas took place with a view to defining the problems involved and the fields in which further investigation is required. The desirability was stressed of making available reliable methods for calculating the thermal cycles which occur during welding. Especially with alloy steels and aluminium alloys, this would enable the welding engineer to produce physically sound welds without the need of long and costly experiments. In the third discussion, Dr. A. A. Wells (British Welding Research Association) described one simplified method of calculation, other methods were given by Dr. P. H. Price (Sheffield University) and Dr. A. V. Brancker (Northern Aluminium Co., Ltd.). Experimental results were reported on by Mr. E. V. Beatson, and in the final session by Mr. D. R. Milner (Birmingham University). It was agreed that further work, both theoretical and practical, was required, and a construction panel was set up to collect and distribute information. Inquiries should be addressed to :—The Secretary (Heat Flow Panel), The Institute of Welding, 2, Buckingham Palace Gardens, London, S.W.1.

FATIGUE OF METALS LECTURE COURSE.—A week's residential course on the fatigue of metals is being held at the University of Nottingham from Monday, September 12th, until Friday, September 16th, inclusive. The course has been organised by a joint committee of industry and the engineering departments of the University under the chairmanship of Mr. G. Forrest. As this University carries out a considerable amount of research in the fatigue of metals, it is quite natural that such a course should be centred on Nottingham. It is intended that the course should present the known facts concerning the fatigue of metals to the practising engineer, and although no formal academic qualifications are required for enrolment, it will be assumed that those attending the course will possess either a degree or the Higher National Certificate in engineering or science. The subjects to be covered are the fundamentals of fatigue (five lectures), the fatigue properties of steels and cast iron (four lectures), the fatigue properties of non-ferrous alloys (three lectures), corrosion fatigue and fretting corrosion, fatigue of aircraft (three lectures), and fatigue testing (four lectures). Residential accommodation for 100 people will be provided in Hugh Stewart Hall, which is situated in the University Park. The fee for the course is ten guineas and that for accommodation seven guineas. All inquiries regarding the course should be addressed to the Secretary, Fatigue of Metals Course, Departments of Civil and Mechanical Engineering, University of Nottingham, University Park, Nottingham.

British Patent Specifications

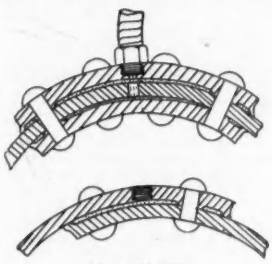
When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification.

Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 2s. 8d. each.

PRESSURE TESTING EQUIPMENT

730,072. February 24, 1953.—Detecting Imperfections in the Seams of Pressure Vessels, Arthur Richards Haworth, 83, Mellington Avenue, East Didsbury, Manchester, 20.

The invention consists of a method of detecting imperfections in the seams or joints of pressure vessels, in which a fluorescent detecting fluid is forced under pressure into the seam through a hole made in one plate. Any escape of fluid along or through the seam is detected by an ultra-violet lamp. The drawing shows the invention as applied to lapped or butted seams of boilers or other pressure or vacuum vessels.



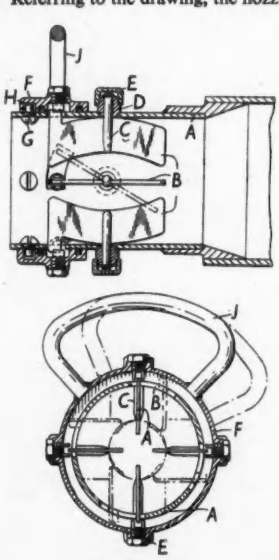
No. 730,072

A small hole is drilled through the outer plate or strap or through the backing plate of the seam to break into the space between the plates, and a pump or syringe, not shown, is coupled by a pipe and nipple to the hole and fluid is injected into the seam. Any imperfection in the plates or along the seams, or along the rivets, allows the escape of the fluid. The injection of the fluid into the seam is assisted by capillary action. It has been found that a fluid consisting of a fluorescent liquid carried by a volatile solvent with good penetrating qualities gives the best results. On leaking and subsequently evaporating, the fluid deposits small quantities of the solution, which may then be detected by means of ultra-violet rays from a portable U.V. lamp.—*May* 18, 1955.

FIRE EXTINGUISHING APPARATUS

730,046. November 3, 1952.—Foam Nozzles, The Pyrene Company, Ltd., Great West Road, Brentford, Middlesex. (*Inventors: Thomas Anthony Henshaw and Cecil Kennerson.*)

The invention relates to nozzles for delivering foam for fire extinguishing purposes which are adjustable during operation to vary the extent to which the foam delivered through the nozzle spreads out laterally. Referring to the drawing, the nozzle shown



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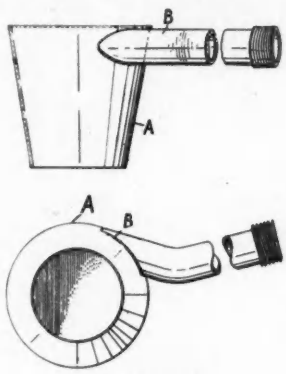
is intended for use with a foam generator to which it is joined by a connector. The nozzle consists of an open-ended tube *A* in which there are four vanes *B*. Each vane is a flat plate fixed midway in a split pin *C*, which projects radially into the tube from a socket *D* which forms a bearing for the pin and is covered by a cap *E*. Each vane can turn with its pin about its axis. The width of the vanes is less than the radius of the tube and they leave a small radius unobstructed at the central zone of the nozzle. Both the inner and the outer of the vane edges are curved, the outer edge being curved to conform with the inner wall of the tube in the position of maximum inclination, as shown in dotted lines in the lower view. The vanes are all mechanically connected to a ring *F* encircling the tube *A* and mounted to turn on it. The ring is guided by the engagement of screws *G* in an annular slot *H* in the ring. Seals are provided between the ring and the tube. The ring is fixed to the handle *J*, by which the nozzle is held when in use. In operation, the nozzle serves two purposes: first, by a small variation in the vane angle the effective zone of the spray can be adjusted without much interference with the flow, and without reducing the effective range; secondly, by increasing the angle of the vane further the effective range may be shortened. —*May* 18, 1955.

730,406. October 24, 1952.—Apparatus for Applying Powder to Fires, The Pyrene Company, Ltd., Great West Road, Brentford, Middlesex. (*Inventor: Kenneth George Kimber.*)

Fires may be extinguished by the application of dry powder, which may consist principally of inert material or of sodium bicarbonate or other substance which will give off a gas. The object is to provide a device by which powder applied under pressure from the fire extinguisher may be applied gently to the seat of the fire. By the invention the powder is



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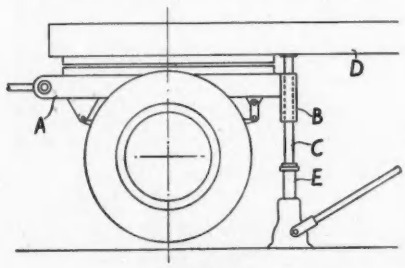
conveyed to the fire in a stream of gas and the stream is caused to travel round the smooth inner surface of a circular wall above the fire to reduce its velocity so that it drops gently downwards on to the fire. In addition the powder will largely separate from the gas by centrifugal action, with the result that the cloud of powder particles falling on to the fire has a higher density and greater smothering power. In one form the device consists of a frusto-conical hollow member *A*, 3in long axially, with a closed large end 3in in diameter and an open small end 2in in diameter, and a pipe *B* which enters the hollow member tangentially. This pipe is ¾in in diameter and may be of any desired length, its other end being connected to a dry-powder fire-extinguishing apparatus not shown. The hollow member may be made in various other forms.—*May* 25, 1955.

ROAD TRANSPORT

730,429. April 2, 1953.—Jacking of Wheeled Vehicles with Steerable Bogies, Berners Charles D'Eye Farrington, 61, Norton Road, Letchworth, Hertfordshire, and Hands (Letchworth), Ltd., New Icknield Way, Letchworth, Hertfordshire.

The invention relates to means for facilitating jacking of a vehicle such as a trailer, having a steerable bogie. The drawing shows the front end of a trailer



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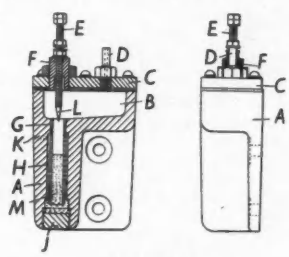
having a steerable bogie or forecarriage *A*. At the rear corners of the forecarriage are attached hollow guides *B* in which slide struts *C*. When it is desired to support the vehicle rigidly the bogie is set so that the upper ends of the struts *C* can engage the undersides of respective frame members *D* and a jack *E* is placed between the ground and each strut. Extension of the jack will cause the top end of the strut to abut under the frame members *D* of the trailer, while the guide member maintains the strut in position. The rear end of the trailer would normally be supported by any suitable means such as a further pair of jacks abutting under some portion of the frame.—*May* 25, 1955.

INTERNAL COMBUSTION ENGINES

729,951. December 4, 1952.—Controlling Apparatus for Automatically Stopping Engines, F. Perkins, Ltd., of Peterborough, Northamptonshire, and Joseph Valderrame Gil, of the company's address.

The invention relates to internal combustion engines, its main object being to provide controlling apparatus for automatically stopping the engine in the event of the engine reaching speeds in excess of a predetermined value. Referring to the drawing, the apparatus consists of a mercury switch constructed in the form of a rectangular metal body *A* having a sealed chamber in the upper part formed by a shallow recess *B* closed by a cover *C*. This cover fits over the top of the body and contains apertures in which are mounted, by means of airtight joints, a tubular connector *D* leading to the induction manifold of the engine, and a rod switch contact *E* which projects into the sealed chamber *B* through a tubular insulator *F*. A substantially straight tube *G* extends from the floor of the sealed chamber *B* and terminates in the lower part of a space *H* which is closed at the bottom of the body by a detachable plug *J* and communicates with the atmosphere by an air vent *K*. The diameter of the cylindrical space is slightly larger than the diameter of the tube *G* so that an annular space is formed between them. The rod contact *E* has a point *L* at its lower end and is arranged to terminate just within the upper end of the tube *G* which is filled with mercury *M* to within about ¼in of the top of the tube. The arrangement is such that when the engine is at rest or is being motored to effect a start, the mercury *M* in the tube *G* and in the space *H* will be at substantially the same level. When the pressure in the induction manifold begins to fall due to a rise in engine speed the pressure in the sealed chamber *B* will fall correspondingly and cause the mercury to rise in the inner tube *G* and fall in the space *H*. This movement continues until a difference of about 1in between the two levels is



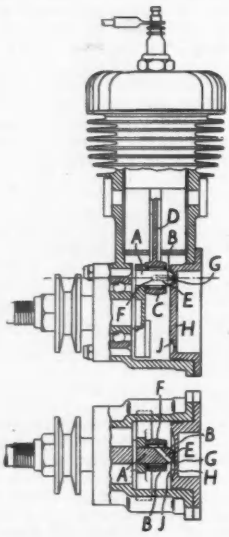
No. 729,951

reached, which corresponds to a normal depression in the induction manifold at which a pneumatically governed engine operates. Under these conditions, the arrangement is such that the mercury in the tube *G* is still clear of the end *L* of the rod contact *E*, but in the event of the engine speed rising above the governed speed, the further fall in pressure in the induction manifold will cause a further rise in the mercury level until it reaches the end *L* of the rod contact and completes an electric circuit through a solenoid or other electrical device which is arranged to actuate a fuel control device to cut off the supply of fuel and stop the engine. In order that the critical speed at which the switch operates may be varied, the rod contact *E* is mounted so that its position with respect to the mercury tube may be varied. The end *L* of the rod contact which engages with the mercury may be either pointed or flattened, according as to whether a gradual or sudden build-up of current in the solenoid is required. Modified designs are also shown in the specification.—*May* 11, 1955.

730,537. December 30, 1953.—The Lubrication of Two-Stroke, Single-Cylinder Engines, William Thomas Teagle, Blackwater, Truro, Cornwall.

The invention relates to two-stroke, single-cylinder internal combustion engines in which lubrication is by mixing oil with the fuel and has for its object to improve the lubrication of the big end bearing. In the drawing is shown the engine which forms the subject of Specification No. 714,619. The crank pin *A* is of sufficient length to leave a portion *B* exposed beyond the big end bearing *C* of the connecting-rod *D*. Extending through the crank pin

obliquely is a passage *E*. One end *F* of the passage opens out of that portion of the crank pin which lies within the big end bearing, and the other end *G* opens out of the exposed portion *B*. The exposed end of the passage is such that, when the engine is running, some of the oil-containing fuel-and-air mixture in the crankcase is scooped into the passage



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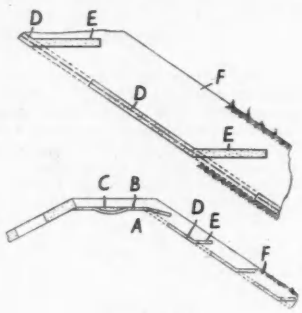
and directed through it on to the big end bearing. When the invention is employed in an engine in which the crankshaft bearings are on one side of the axis of the cylinder, the intake of the mixture into the passage *E* can be assisted by providing in the inner face of the cover-plate *H* at the end of the crankcase an annular recess *J* for receiving the exposed portion of the pin. The mixture entering the recess is partially prevented by the walls from being expelled so that an increased amount of the mixture is scooped into the passage.—*May* 25, 1955.

CIVIL ENGINEERING

729,622. May 12, 1953.—Sea or other Defensive Walls, Charles Herbert Dobbie, 58, Victoria Street, Westminster, London, S.W.1.

The invention relates to sea or other defensive walls, such as river or canal embankments and the like. Referring to the drawing, *A* denotes the body of a clay or earth wall. Such walls tend to develop a crack at the top centre, and in order to prevent access of water to such crack an impermeable revetment or covering of plastic material such as asphalt is applied over the top of the wall as indicated at *B* in the lower



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view. Instead of asphalt thin concrete or other slabs which are flexibly interlocked may be employed. Preferably, a groove or hollow, such as is indicated at *C*, will be formed centrally at the wall top and filled with plastic material such as asphalt to provide a reserve or greater thickness of impermeable material in the region of the centre top of the wall. The application of an impermeable covering to the back slope of the wall presents difficulties, and to meet these difficulties the use of a louvre type revetment at the rear of the wall is proposed. The elements *D*, comprising such revetment may be formed of asphalt, concrete or any other inert material. As will be clearly seen from the drawing, the louvre elements *D*, each of which consists of a flat strip having an outwards directed lip *E* along the lower edge when in use, are preferably disposed under a layer of soil *F* at the back of the wall. The elements *D* extend lengthwise of the wall in horizontal rows spaced one above the other, which allows for the penetration of moisture into the clay of the wall by rainfall on the covering of soil or vegetation.—*May* 11, 1955.

METALLURGY

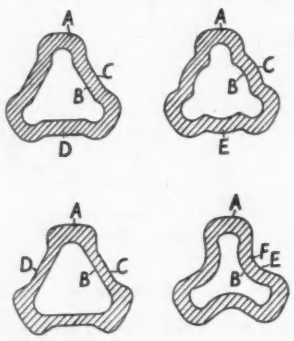
730,388. May 22, 1952.—The Manufacture of Foundry Pig Iron, Compagnie Generale des Conduites d'Eau, Les Vennes, Liege, Belgium.

The object of the invention is to provide an improved process for producing economically good quality foundry pig iron starting with low grade ores. The process consists in producing first in a blast furnace from ores of low iron content, and particularly low grade acid ores, by the acid or super-acid process a low grade pig iron with a low carbon content and a high sulphur content, and then in charging the iron into a neutral or preferably basic hot blast cupola furnace operating under reducing conditions and with a quantity of fuel in excess of that required for melting and with a greater quantity of slag than would normally be used in a cupola furnace. Alloying elements required in the foundry iron such as manganese and silicon are added in the cupola and the iron is heated to a temperature of from 1450 deg. to 1600 deg. Cent. for casting. The alloying elements may be added in the form of ores, oxides or even slags.—*May* 25, 1955.

RAILWAY ENGINEERING

730,533. November 12, 1953.—Railway Rails, The Industrial Trustee Holding Company, 12, Avenue de L'Arsenal, Luxembourg.

According to the invention, it is proposed to provide a railway rail having three running surfaces disposed at 120 deg. from each other. In the drawings



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it has not been considered necessary to illustrate anything other than the transverse section of the railway rails in view of the fact that this is all that is necessary to understand the invention. Moreover, the same reference numerals relate to similar parts. The drawings show that the railway rail is made from a hollow body substantially triangular in shape, that is to say the cross-section is in the form of an equilateral triangle and has a running surface *A* at each apex. Moreover, the polygonal contours, *B* and *C*, bounding the section inside and outside have similar shapes, a constant thickness being provided round the entire periphery of the hollow body. Between the running surfaces there extend plane portions *D*, or curved portions which may be convex *E* or concave *F*.—*May* 25, 1955.

Launches and Trial Trips

Pizarro, cargo ship; built by the Greenock Dockyard Company, Ltd., for the Pacific Steam Navigation Company, Ltd.; length between perpendiculars 476ft, breadth moulded 66ft, depth moulded to upper deck 40ft 8in, deadweight 11,100 tons on 28ft mean draught; service speed 16¼ knots; twelve passengers; five cargo holds, ten 5-ton and four 10-ton derricks and one 70-ton heavy derrick; electric deck machinery; three 260kW diesel-driven generators; one set of Parsons three-cylinder, reaction, double reduction geared turbines, service power 9400 s.h.p. at 108 propeller r.p.m., maximum power 10,340 s.h.p., steam supplied at 415 lb per square inch and 750 deg. Fah. by two Babcock and Wilcox single-pass water-tube boilers. Launch, May 19th.

Hemiplecta, oil tanker; built by Cammell, Laird and Co. (Shipbuilders and Engineers), Ltd., for Shell Tankers, Ltd.; length between perpendiculars 530ft, breadth moulded 69ft 3in., depth moulded 39ft, summer draught 29ft 9in, deadweight 18,000 tons; thirty-three cargo oil tanks, one main cargo pump room, steam deck machinery; two 550kW turbine-driven alternators, one 200kW diesel-driven generator; one set of two-cylinder double reduction geared turbines, 8250 s.h.p., steam supplied at 500 lb per square inch gauge and 800 deg. Fah. by two Babcock and Wilcox water-tube boilers. Launch, May 23rd.

Manes, cargo ship: built by the Burntisland Shipbuilding Company, Ltd., for the Compania de Navegacion Oriental de Panama, S.A.; length between perpendiculars 435ft, breadth 61ft 9½in., depth moulded to weather deck 38ft. 3in., deadweight 12,450 tons, draught loaded 29ft.; five cargo holds, four 3-ton, ten 5-ton and two 25-ton derricks, electric deck machinery; three 200kW diesel-driven generators, one 20kW diesel-driven generator; Sulzer two-stroke, single-acting diesel engine, seven cylinders 720mm diameter by 1250mm stroke, 4825 b.h.p. at 125 r.p.m. Launch, May 23rd.

Loch Ard, cargo ship; built by Ferguson Brothers (Port Glasgow), Ltd., for David MacBrayne, Ltd.; length 170ft, breadth 34ft, depth 18ft 9in; two cargo holds, electric deck machinery, bipod mast; British Polar diesel engine, six cylinders, trial speed 12 knots. Launch, May 23rd.

Red Crest, trawler; built by John Lewis and Sons, Ltd., for the Iago Steam Trawler Company; length between perpendiculars 135ft, breadth 26ft 6in., depth 13ft 3in; electric deck machinery, diesel-driven generator for trawl winch, fish room 930 cubic feet; British Polar diesel engine, five cylinders, 800 b.h.p. at 250 r.p.m. Launch, May 24th.

Stanvac Australia, oil tanker; built by John Brown and Co. (Clydebank), Ltd., for the Standard-Vacuum Transportation Company, Ltd.; length 628ft, breadth 82·5ft, depth 42·5ft, draught 32ft, deadweight 26,500 tons, speed 17 knots; four 750 tons per hour cargo oil pumps; one set of double reduction geared high-pressure steam turbines, 12,500 s.h.p. at 112 r.p.m. Launch, May 24th.

Navua, coaster; built by Henry Robb, Ltd., for the Union Steam Ship Company of New Zealand, Ltd.; length between perpendiculars 250ft, breadth moulded 41ft 6in, depth moulded to upper deck 17ft 9in, deadweight 2000 tons on 16ft mean draught, speed 11 knots; four holds, ten 5-ton derricks, MacGregor hatch covers, electric deck machinery, three 114kW diesel-driven generators; Clark-Sulzer mark T.P.D.48 two-stroke diesel engine, five cylinders, 1500 b.h.p. at 225 r.p.m. Trial, May 24th.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

CEMENT AND CONCRETE ASSOCIATION

Tues., June 14th.—Prestressed Concrete Development Group: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Prestressed Concrete Structures in Germany with Concentrated Tendons." F. Leonhardt, 6 p.m.

INCORPORATED PLANT ENGINEERS

Thurs., June 16th.—Merseyside and N. Wales Branch: Royal Institution, Colquitt Street, Liverpool, "Liquid Fuel Firing." S. S. Whitehead, 7.15 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sun. to Sat., June 19th to 25th.—London: Twenty-second International Foundry Congress.

INSTITUTE OF INDUSTRIAL ADMINISTRATION

Wed., June 15th and 22nd.—London Branch: Fyvie Hall, The Polytechnic, Regent Street, London, W.1, Higher Management Lectures, "The Practice of General Management," 6.30 p.m.

INSTITUTE OF PETROLEUM

Thurs., June 30th.—Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, Four papers outlining "The Story of the Co-ordinating Research Council," by M. K. McLeod, T. B. Rendel, E. S. Macpherson and W. J. Sweeney, 3.30 and 5.30 p.m.

INSTITUTE OF PHYSICS

Thurs., June 23rd.—Non-Destructive Testing Group: Royal Technical College, Glasgow, Annual General Meeting, 9 a.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Thurs., June 16th.—London Centre: Day visit to the Metropolitan Police Motor Driving School, Hendon, London, N.W.9.

INSTITUTION OF ELECTRICAL ENGINEERS

To-day and Sat., June 10th and 11th.—Summer Meeting in Scotland.

INSTITUTION OF MINING AND METALLURGY

Thurs., June 16th.—General Meeting, Geographical Society, Burlington House, Piccadilly, London, W.1, "Application of Plastic Igniter Cord to Blasting Operations in Metalliferous Mines," R. Haslam, R. D. J. Owens and J. Hancock, "Concealed Lead-Zinc Fields in England," G. A. Schnellmann, 5 p.m.

INSTITUTION OF MINING ENGINEERS

Wed. to Fri., June 15th to 17th.—Summer Meeting in Edinburgh.

INSTITUTION OF SANITARY ENGINEERS

To-day and Sat., June 10th and 11th.—Summer Meeting: To-day: Caxton Hall, Westminster, London, S.W.1, "The Reconstruction of the Sewage Works at Richmond, Surrey," J. D. Wall, 6 p.m. Saturday: Visit to Richmond Sewage Disposal Works, Surrey, 10 a.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Fri. and Sat., June 10th and 11th.—Annual Conference of Mining Surveyor Members: Caledonian Hotel, Edinburgh, Friday: "The Scottish, English and Welsh Coalfields: Geological Similarities and Differences," G. H. Mitchell, 10.30 a.m.—Saturday: "Survey Problems Arising Out of Colliery Reconstruction," Clifford Beevers, 10.30 a.m.

Thurs., June 16th.—Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, Conference of Chartered Quantity Surveyors, 10.15 a.m.